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(54) **PRENATAL, PERINATAL, OR POSTNATAL MENTAL OR EMOTIONAL DISTRESS IDENTIFICATION AND PREDICTION**

(71) Applicant: **Oura Health Oy**, Oulu (FI)

(72) Inventor: **Neta A. Gotlieb**, Albany, CA (US)

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A61B 5/145	(2006.01)

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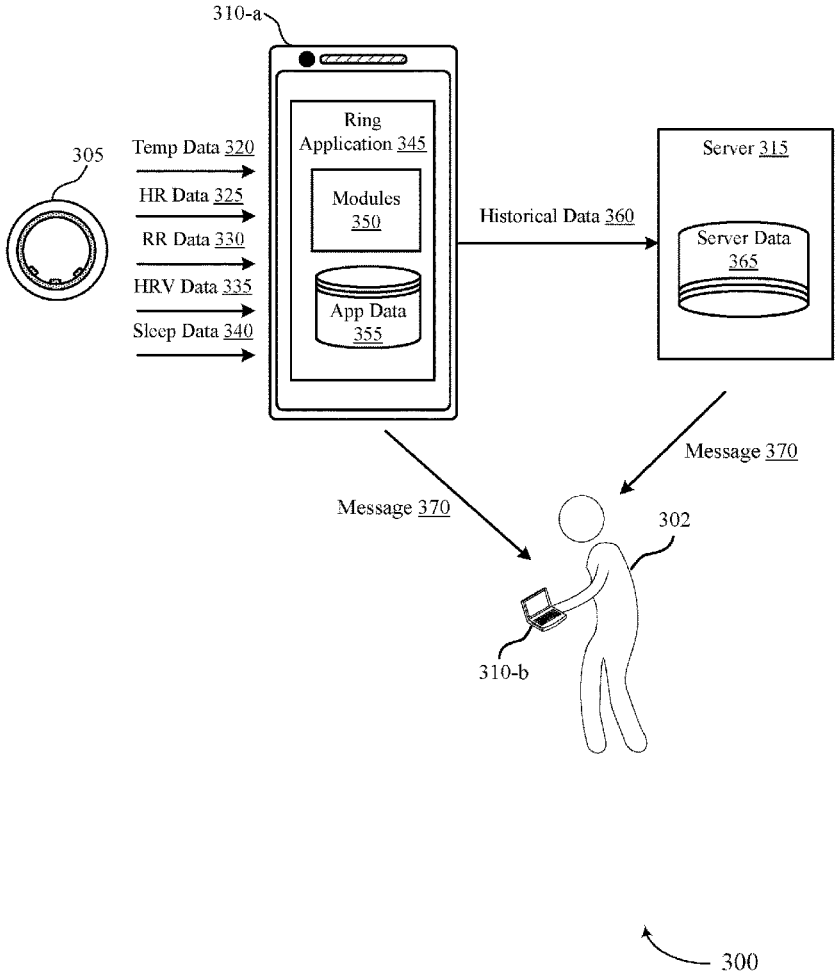
(57) **ABSTRACT**

Methods, systems, and devices for prenatal, perinatal, or postnatal mental or emotional distress identification and prediction are described. A system may be configured to receive physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy and collected over a plurality of days, where the physiological data includes at least temperature data. Additionally, the system may be configured to determine a time series of temperature values. The system may then identify that the temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user and detect an indication of one or more conditions of mental or emotional distress experienced during the prenatal, perinatal, or postnatal period. The system may generate a message for display on a graphical user interface on a user device that indicates the indication of the one or more conditions of mental or emotional distress.



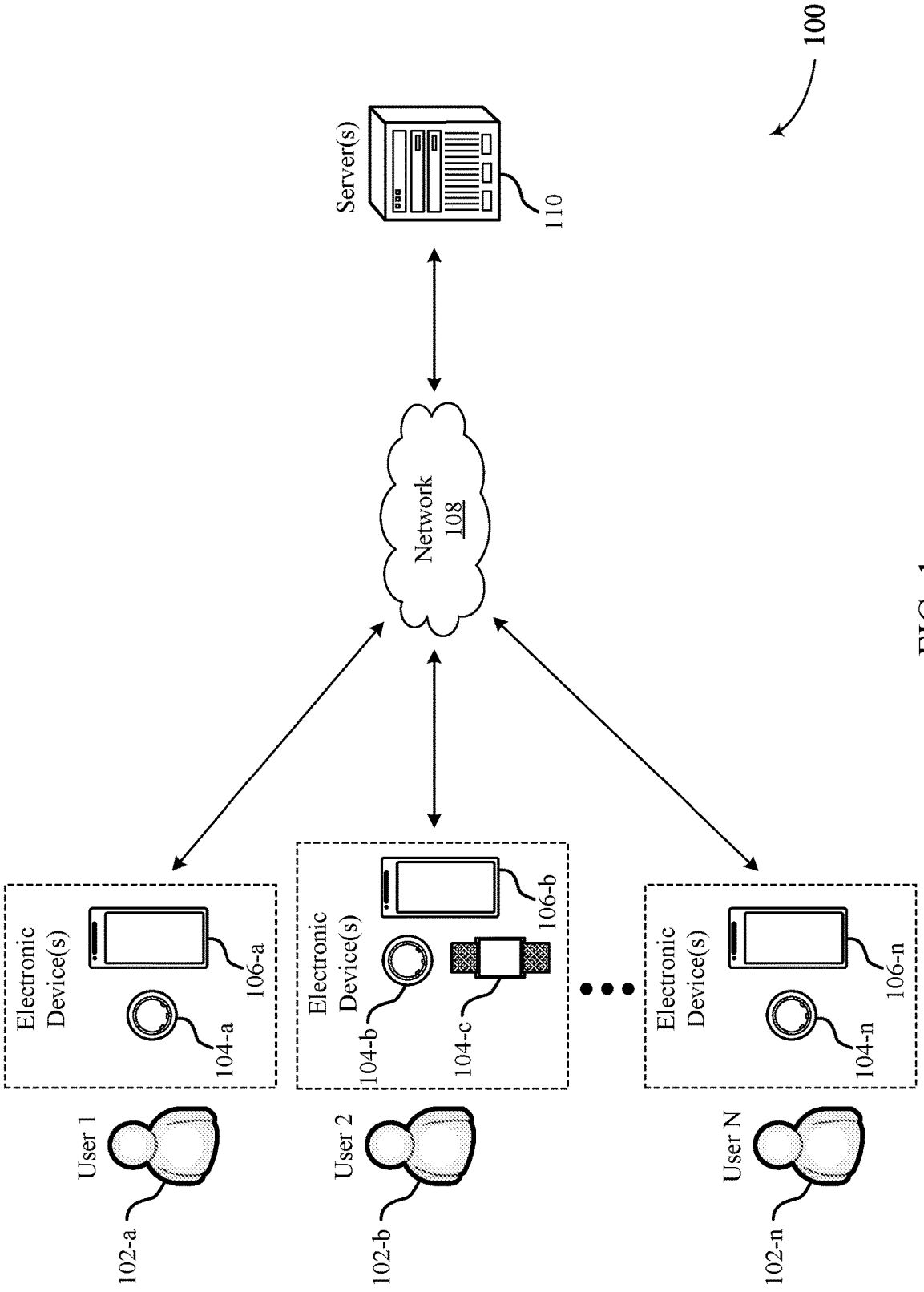

100
Server(s)
110
Network
108
Electronic
Device(s)
106-a
104-a
Electronic
Device(s)
106-b
104-b
104-c
Electronic
Device(s)
106-n
104-n
User 1
102-a
User 2
102-b
User N
102-n

FIG. 1

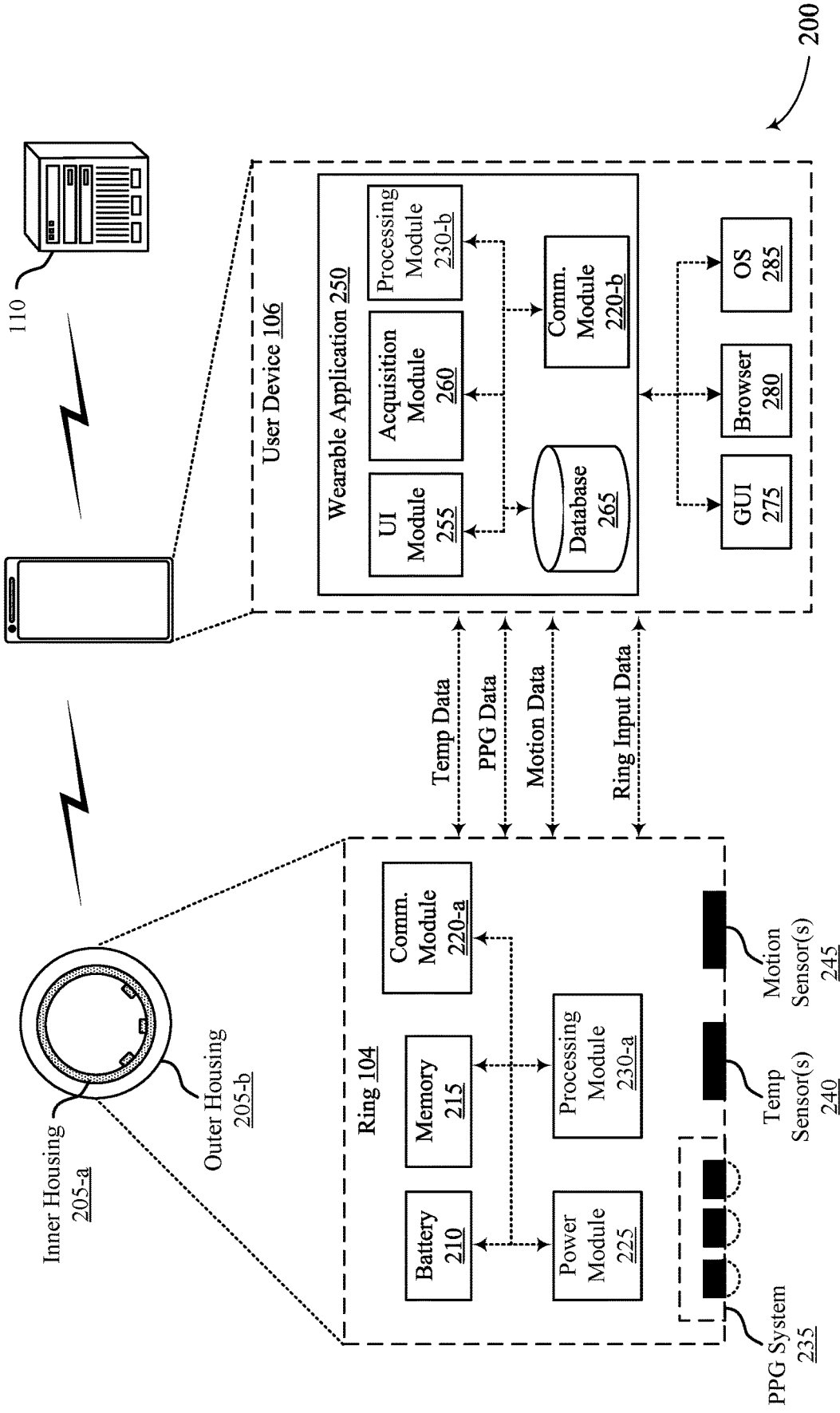

200
110
User Device 106
Wearable Application 250
UI Module 255
Acquisition Module 260
Processing Module 230-b
Database 265
Comm. Module 220-b
GUI 275
Browser 280
OS 285
Temp Data
PPG Data
Motion Data
Ring Input Data
Ring 104
Inner Housing 205-a
Outer Housing 205-b
Comm. Module 220-a
Memory 215
Processing Module 230-a
Battery 210
Power Module 225
PPG System 235
Temp Sensor(s) 240
Motion Sensor(s) 245

FIG. 2

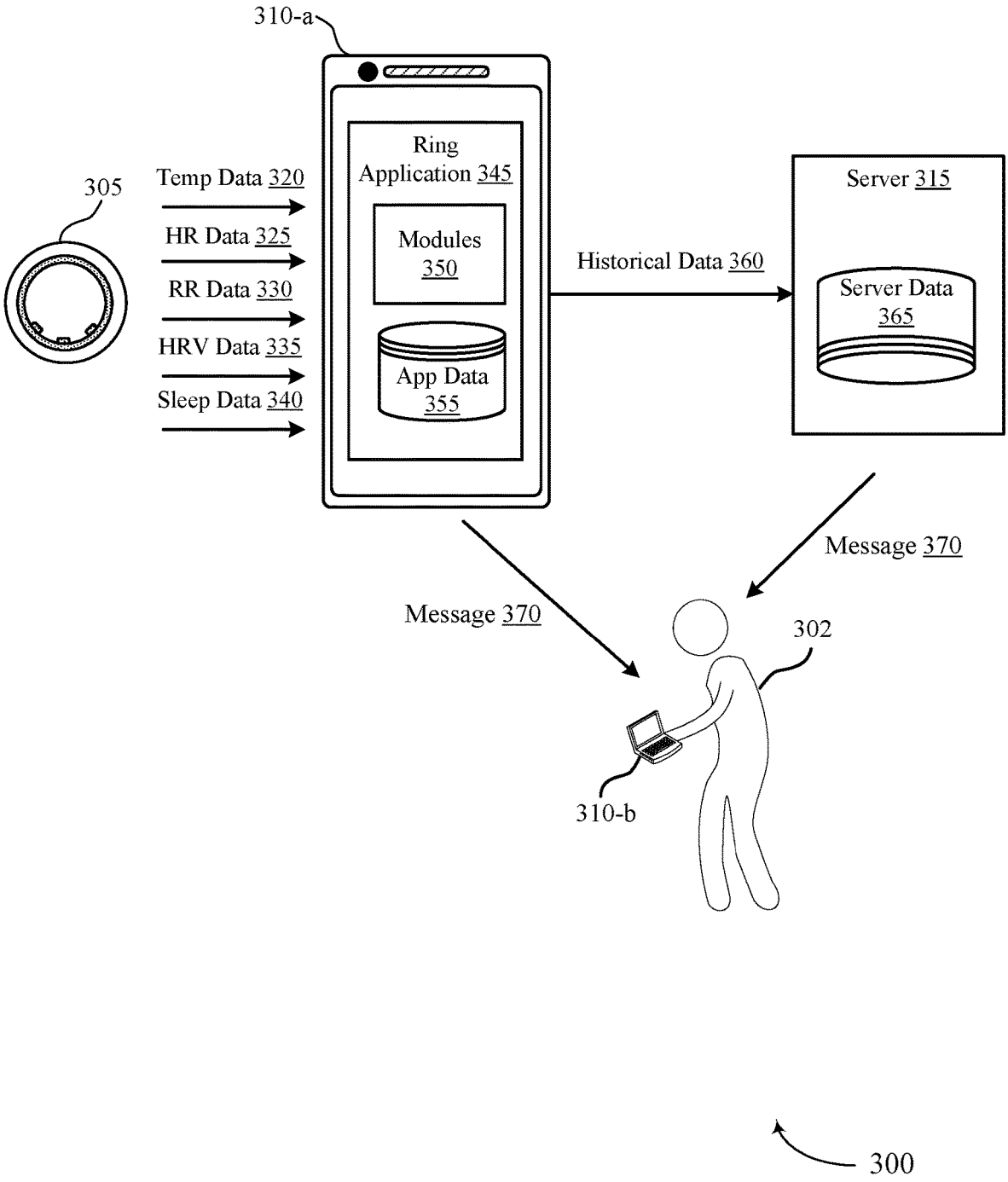

310-a
Ring Application 345
Modules 350
App Data 355
305
Temp Data 320
HR Data 325
RR Data 330
HRV Data 335
Sleep Data 340
Historical Data 360
Server 315
Server Data 365
Message 370
Message 370
302
310-b
300

FIG. 3

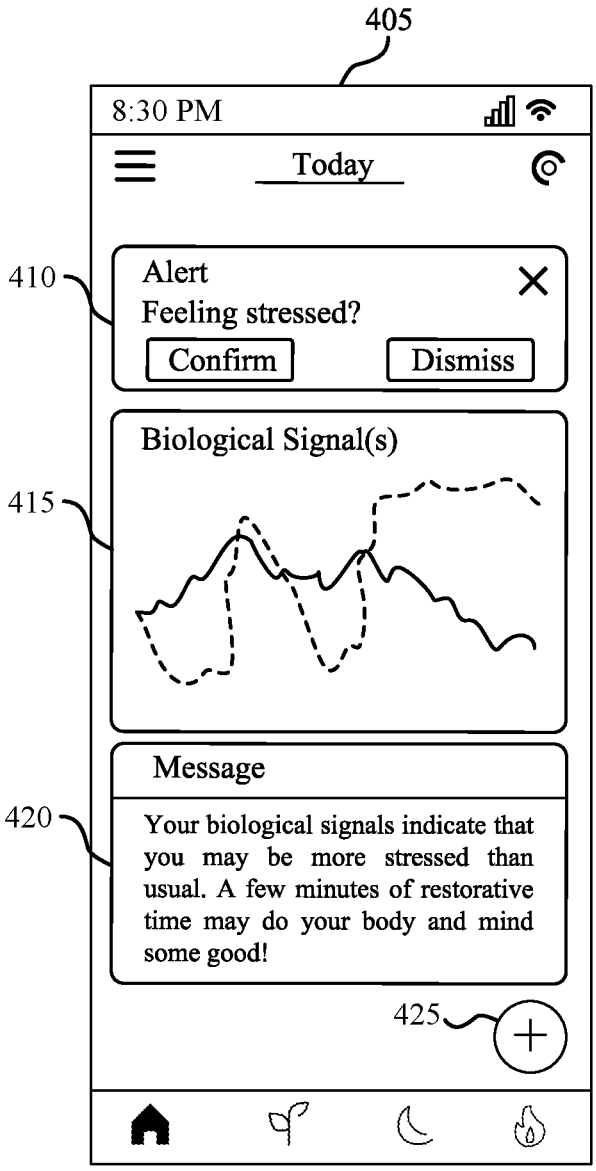

405
8:30 PM
Today
410
Alert
Feeling stressed?
Confirm
Dismiss
Biological Signal(s)
415
Message
420
Your biological signals indicate that you may be more stressed than usual. A few minutes of restorative time may do your body and mind some good!
425
400

FIG. 4

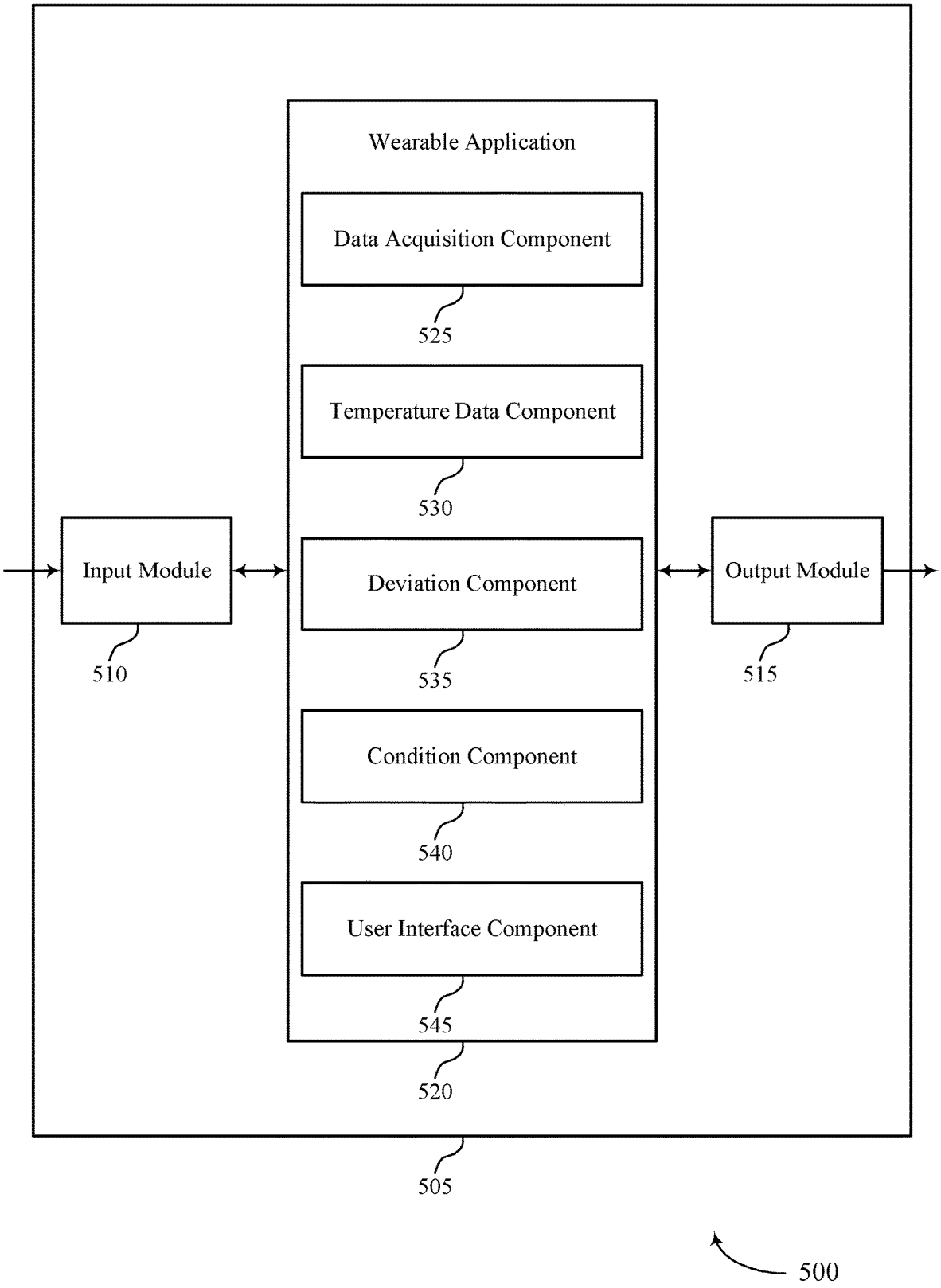

Wearable Application
Data Acquisition Component
525
Temperature Data Component
530
Input Module
Deviation Component
Output Module
510
535
515
Condition Component
540
User Interface Component
545
520
505
500

FIG. 5

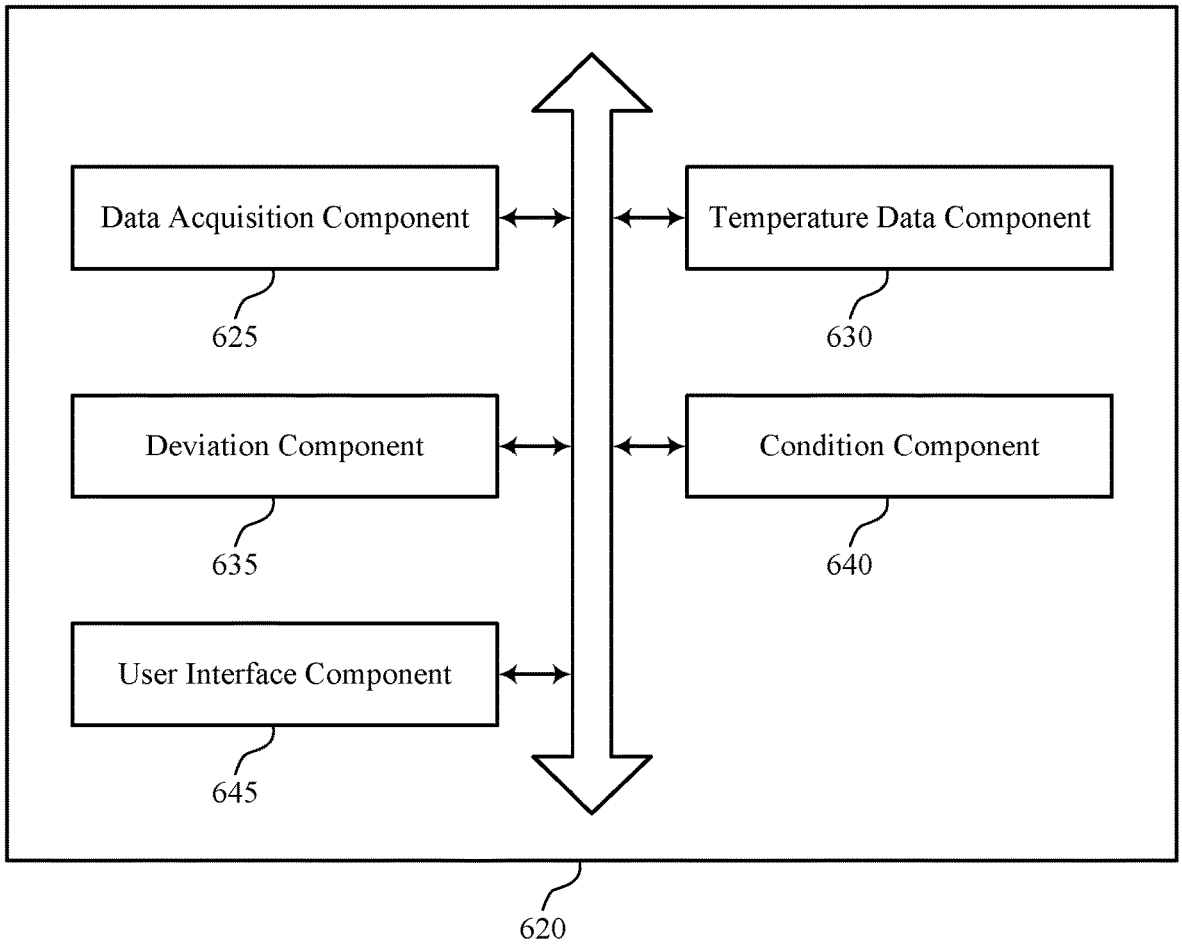

Data Acquisition Component
625
Temperature Data Component
630
Deviation Component
635
Condition Component
640
User Interface Component
645
620
600

FIG. 6

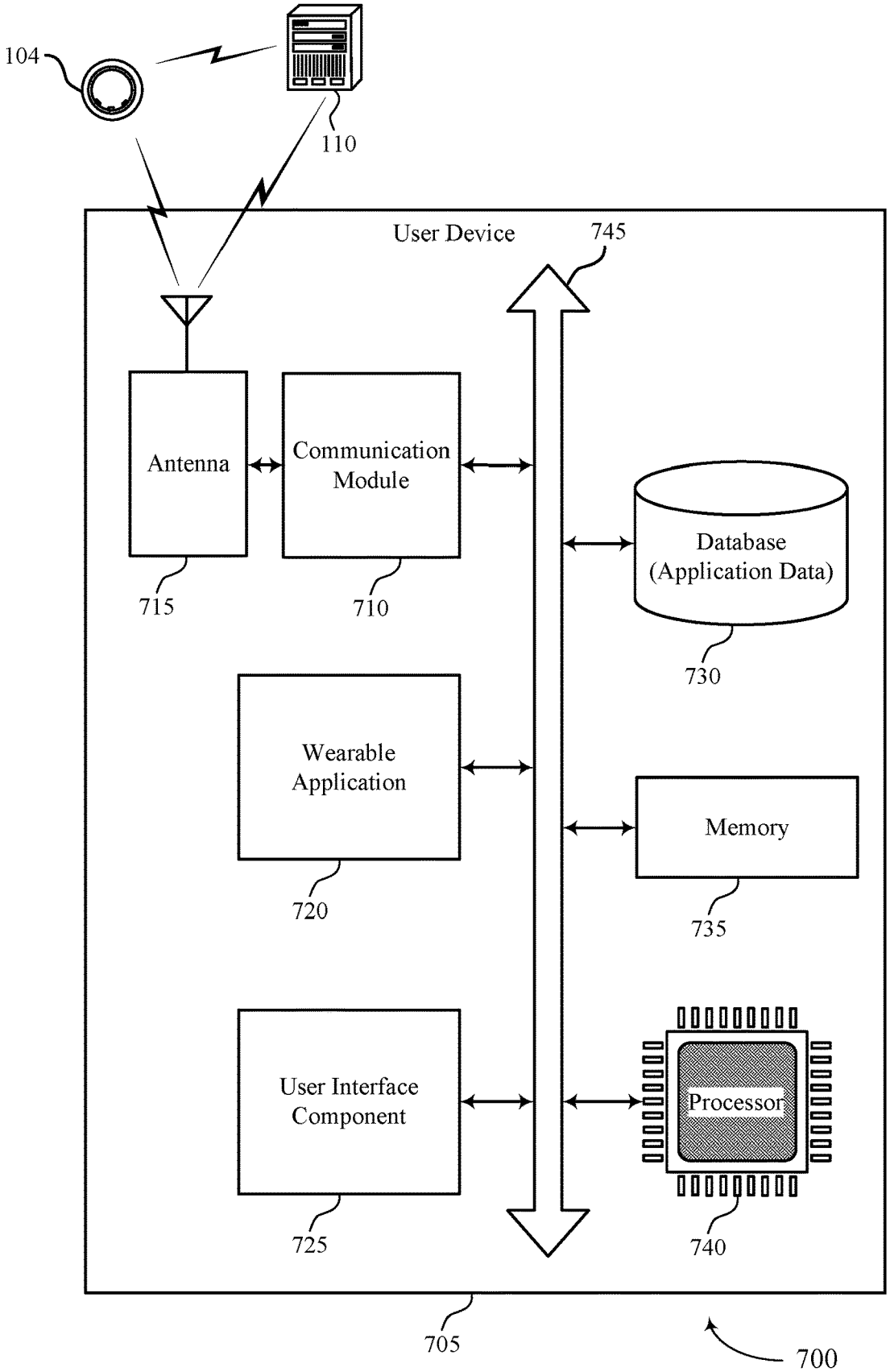

104
110
User Device
745
Antenna
Communication Module
715
710
Database (Application Data)
730
Wearable Application
720
Memory
735
User Interface Component
725
Processor
740
705
700

FIG. 7

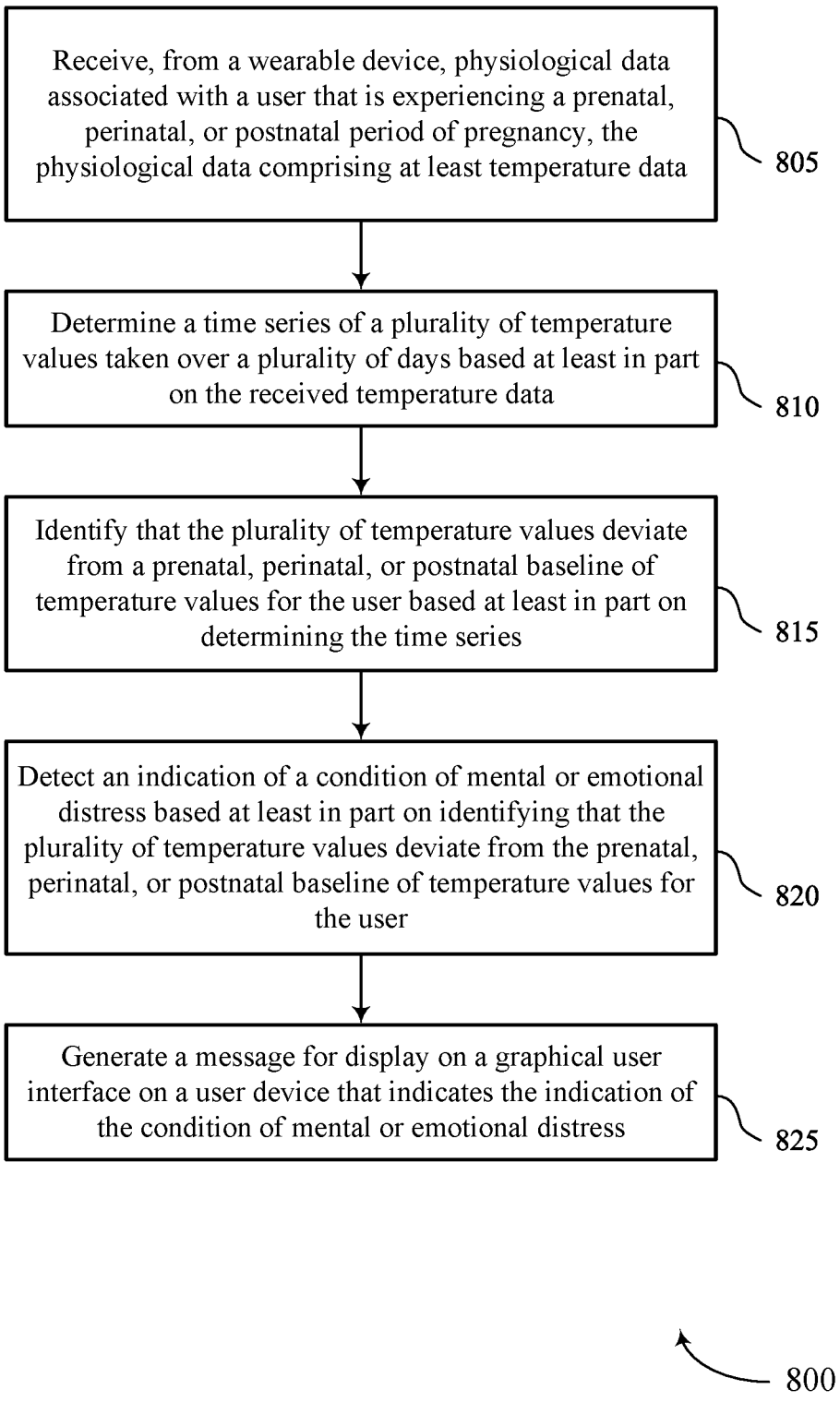

Receive, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data
805
Determine a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data
810
Identify that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series
815
Detect an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user
820
Generate a message for display on a graphical user interface on a user device that indicates the indication of the condition of mental or emotional distress
825
800

FIG. 8

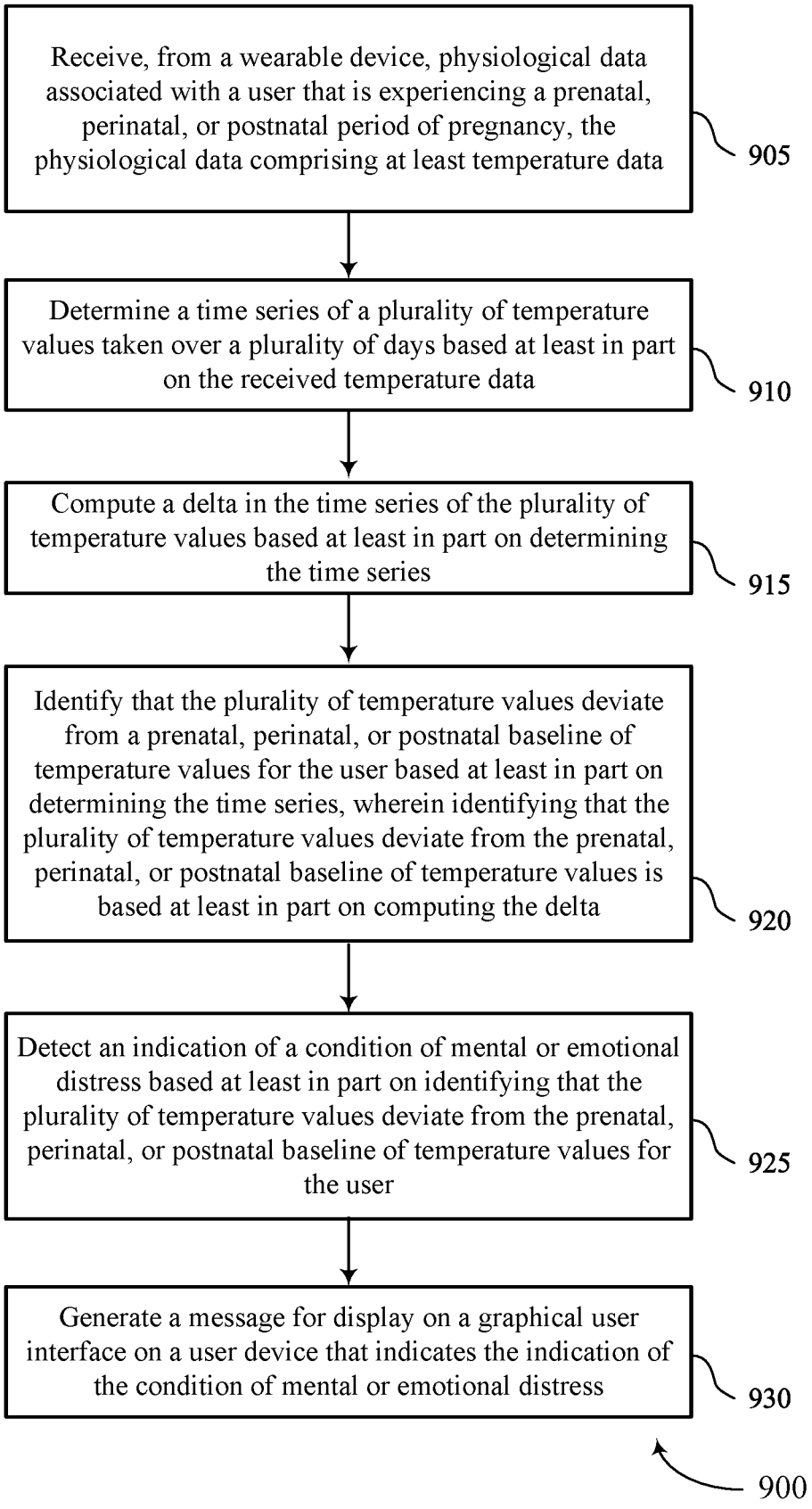

Receive, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data
905
Determine a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data
910
Compute a delta in the time series of the plurality of temperature values based at least in part on determining the time series
915
Identify that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series, wherein identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values is based at least in part on computing the delta
920
Detect an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user
925
Generate a message for display on a graphical user interface on a user device that indicates the indication of the condition of mental or emotional distress
930
900

FIG. 9

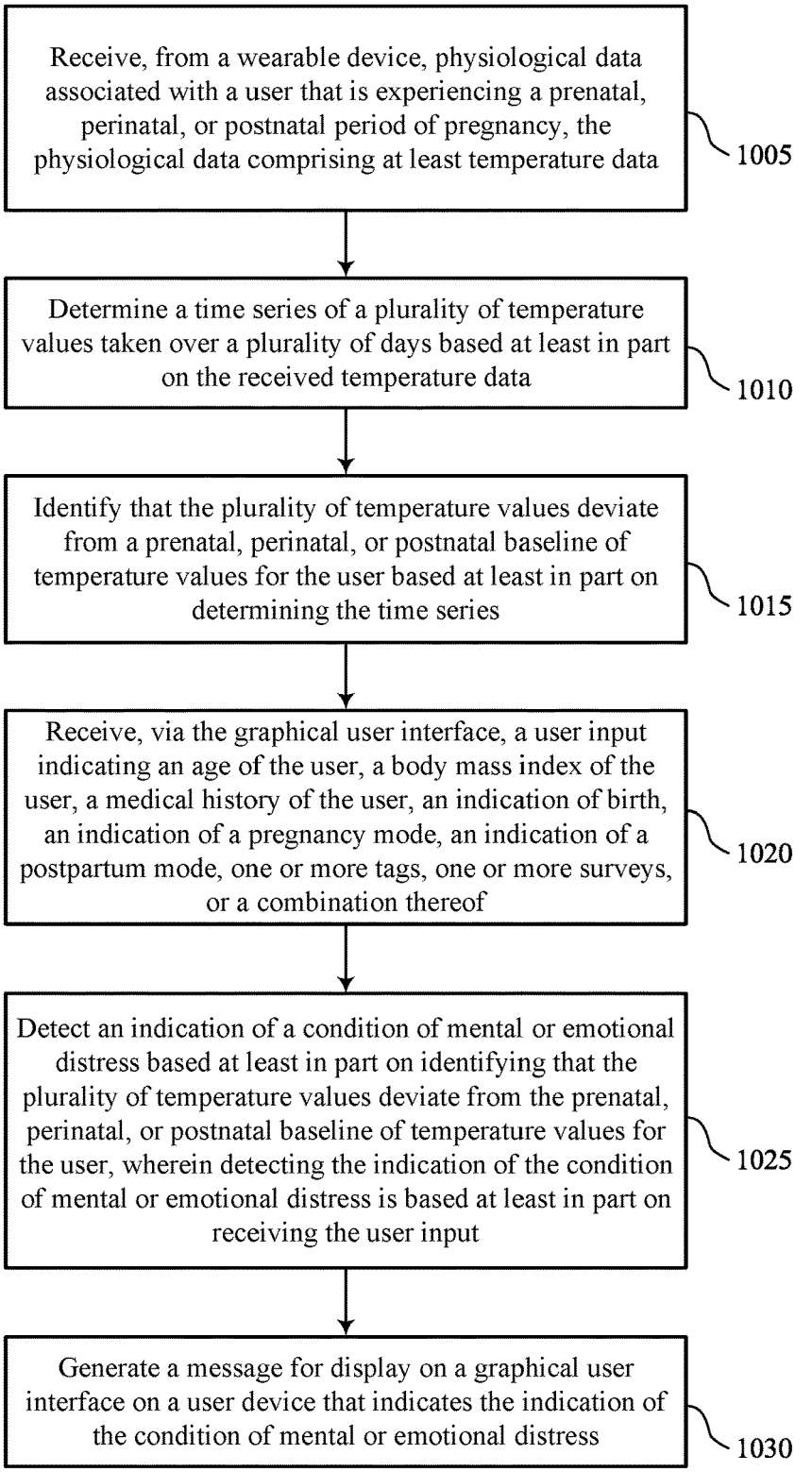

Receive, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data
1005
Determine a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data
1010
Identify that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series
1015
Receive, via the graphical user interface, a user input indicating an age of the user, a body mass index of the user, a medical history of the user, an indication of birth, an indication of a pregnancy mode, an indication of a postpartum mode, one or more tags, one or more surveys, or a combination thereof
1020
Detect an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on receiving the user input
1025
Generate a message for display on a graphical user interface on a user device that indicates the indication of the condition of mental or emotional distress
1030
1000

FIG. 10

PRENATAL, PERINATAL, OR POSTNATAL MENTAL OR EMOTIONAL DISTRESS IDENTIFICATION AND PREDICTION

CROSS REFERENCE

[0001] The present Application for Patent claims the benefit of U.S. Provisional Patent Application No. 63/394,279 by GOTLIEB et al., entitled "PRENATAL, PERINATAL, OR POSTNATAL MENTAL OR EMOTIONAL DISTRESS IDENTIFICATION AND PREDICTION," filed Aug. 1, 2022, assigned to the assignee thereof, and expressly incorporated by reference herein.

FIELD OF TECHNOLOGY

[0002] The following relates to wearable devices and data processing, including prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data.

BACKGROUND

[0003] Some wearable devices may be configured to collect data from users associated with body temperature and heart rate. Many users have a desire for more insight regarding their physical health, including their sleeping patterns, activity, and overall physical well-being. In particular, many users may have a desire for more insight regarding women's health, including their menstrual cycle, ovulation, fertility patterns, pregnancy, and postpartum period.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. **1** illustrates an example of a system that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure.

[0005] FIG. **2** illustrates an example of a system that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure.

[0006] FIG. **3** illustrates an example of a system that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure.

[0007] FIG. **4** illustrates an example of a graphical user interface (GUI) that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure.

[0008] FIG. **5** shows a block diagram of an apparatus that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure.

[0009] FIG. **6** shows a block diagram of a wearable application that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure.

[0010] FIG. **7** shows a diagram of a system including a device that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure.

[0011] FIGS. **8** through **10** show flowcharts illustrating methods that support prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0012] Some wearable devices may be configured to collect physiological data from users, including temperature data, heart rate data, and the like. Acquired physiological data may be used to analyze the user's movement and other activities, such as sleeping patterns. Many users have a desire for more insight regarding their physical health, including their sleeping patterns, activity, and overall physical well-being. In particular, many users may have a desire for more insight regarding women's health, including their menstrual cycle, ovulation, fertility patterns, pregnancy, and postpartum period. However, typical cycle tracking or women's health devices and applications lack the ability to provide robust prediction and insight for several reasons.

[0013] First, typical cycle prediction applications require users to manually take their temperature with a device at a discrete time each day. This single temperature data point may not provide sufficient context to accurately capture or predict the true temperature variations indicative of woman's health cycle patterns, pregnancy patterns, and postpartum patterns and may be difficult to accurately capture given the sensitivity of the measuring device to user movement or exertion. Second, even for devices that are wearable or that take a user's temperature more frequently throughout the day, typical devices and applications lack the ability to collect other physiological, behavioral, or contextual inputs from the user that can be combined with the measured temperature to more comprehensively understand the complete set of physiological contributors to a woman's cycle, pregnancy, and postpartum period.

[0014] Accordingly, aspects of the present disclosure are directed to techniques for identifying and predicting an indication of one or more conditions of mental or emotional distress during a prenatal, perinatal, or postnatal period of pregnancy (e.g., relating to a period of time before and after birth). In particular, computing devices of the present disclosure may receive physiological data including temperature data from the wearable device associated with the user and determine a time series of temperature values taken over multiple days. The physiological data may be associated with a user who is experiencing the prenatal, perinatal, or postnatal period of pregnancy. For example, aspects of the present disclosure may identify one or more morphological features from a graphical representation of the time series of temperature values, such as deviations of the time series of temperature values relative to a prenatal, perinatal, or postnatal baseline of temperature values for the user.

[0015] As such, aspects of the present disclosure may detect an indication of one or more conditions of emotional or mental distress of the user based on identifying the morphological features (e.g., deviations). In such cases, an indication of one or more conditions of emotional or mental distress may be associated with temperature values that deviate from the prenatal, perinatal, or postnatal baseline of temperature values of the user. The indication of one or more

conditions of emotional or mental distress may be an example of detecting that the one or more conditions of emotional or mental distress have already happened, are currently happening, and/or that the one or more conditions of emotional or mental distress are predicted to happen in the future.

[0016] In some implementations, the system may analyze historical temperature data from a user and prenatal, perinatal, or postnatal baseline values of the user and identify the indication of the one or more conditions of emotional or mental distress and may generate an indication that indicates the user's one or more conditions of emotional or mental distress. The user may confirm whether the one or more conditions of emotional or mental distress have already occurred as indicated by the system, and the system may incorporate this user input into a predictive function (e.g., a machine learning model for predicting a future condition of emotional or mental distress). The system may also analyze temperature series data in real time and may predict an upcoming condition of emotional or mental distress based on identifying one or more morphological features in the time series of the temperature data and/or based on the user's input.

[0017] For the purposes of the present disclosure, the term "condition of emotional or mental distress" may be used to refer to a health condition or problem that the user may experience during pregnancy and/or postpartum. The one or more conditions of emotional or mental distress may be used to refer to stress experienced during pregnancy, stress experienced during postpartum, postpartum anxiety, postpartum obsessive-compulsive disorder, postpartum panic disorder, postpartum post-traumatic stress disorder, postpartum psychosis, postpartum depression, or any combination thereof. The one or more conditions of emotional or mental distress experienced during the prenatal, perinatal, or postnatal period of pregnancy may be referred to as perinatal and postpartum mood disorders. Perinatal and postpartum mood disorders, such as postpartum depression, may occur in both women and men during pregnancy and the first year after birth.

[0018] Some aspects of the present disclosure are directed to the detection of the one or more conditions of emotional or mental distress before the user experiences symptoms and effects of the conditions of emotional or mental distress. However, techniques described herein may also be used to detect the one or more conditions of emotional or mental distress in cases where the user does not become symptomatic, or does not become aware of their symptoms. In some implementations, the computing devices may identify an indication of the one or more conditions of emotional or mental distress using a temperature sensor. In such cases, the computing devices may estimate the retrospective dates of the one or more conditions of emotional or mental distress without the user tagging or labeling these events.

[0019] In some examples, the computing devices may identify an indication of the one or more conditions of emotional or mental distress based on one or more risk factors associated with one or more conditions of emotional or mental distress during the prenatal, perinatal, or postnatal period of pregnancy. For example, risk factors may include psychosocial factors such as a history of depression or a psychiatric disorder during pregnancy, inadequate social support, emotional isolation, financial strain, stressful life events, disturbed sleep, preterm birth, and biological factors such as genetic risk and sensitivity to hormonal changes.

[0020] In conventional systems, one or more conditions of emotional or mental distress may be detected after the conditions of emotional or mental distress have occurred. For example, conditions of emotional or mental distress may be detected based on symptoms experienced by the user (e.g., increased periods of sadness, difficulty sleeping, fatigue, etc.) before being referred to treatment. However, users should be screened and referred to treatment much sooner. In such cases, the conditions of emotional or mental distress may be detected after occurrence and/or confirmed at an appointment with the clinician. In some cases, one or more conditions of emotional or mental distress may not be diagnosed until a certain week of pregnancy and/or during the postpartum period of pregnancy.

[0021] In some cases, one or more conditions of emotional or mental distress may be undetected or detected after symptoms occur due to the fear of stigma associated with the one or more conditions of emotional or mental distress. For example, when users may be asked by clinicians how they are feeling and/or how are they taking care of their baby, the users may be less likely to provide honest answers for the concerns about the stigma, being judged, or shamed and, thus, less likely to receive treatment and decrease symptoms. As such, techniques described herein may utilize the user's own physiological data to validate feelings of emotional or mental distress to help combat such stigma and improve the willingness and acceptance to receive medical assistance, when appropriate.

[0022] Techniques described herein may continuously collect the physiological data from the user based on measurements taken from a wearable that continuously measures a user's surface temperature and signals extracted from blood flow such as arterial blood flow (e.g., via a photoplethysmogram (PPG) signal), capillary blood flow, or arteriole blood flow. In some implementations, the computing devices may sample the user's temperature continuously throughout the day and night. Sampling at a sufficient rate (e.g., one sample per minute) throughout the night may provide sufficient temperature data for analysis described herein.

[0023] In some cases, continuous temperature measurement at the finger may capture temperature fluctuations (e.g., small or large fluctuations) that may not be evident in core temperature. For example, continuous temperature measurement at the finger may capture minute-to-minute or hour-to-hour temperature fluctuations that provide additional insight that may not be provided by other temperature measurements elsewhere in the body or if the user were manually taking their temperature once per day. As such, data collected by the computing devices may be used to identify and predict when the user experiences one or more conditions of emotional or mental distress.

[0024] Techniques described herein may notify a user, clinician, fertility specialist, care-giver, or a combination thereof of the indication of the one or more pregnancy complications in a variety of ways. For example, a system may generate a message for display on a GUI of a user device that indicates the indication of the one or more conditions of emotional or mental distress. In such cases, the system may cause the GUI of a user device to display a message or other notification to notify the user, clinician, etc. of the detected condition of emotional or mental distress, notify the user of an estimated likelihood of a future con-

dition of emotional or mental distress, make recommendations to the user, and the like. In some implementations, the system may make tag recommendations to a user in a personalized manner.

[0025] The system may also include graphics or text that indicate the data used to make the detection/prediction of a likely condition of emotional or mental distress. For example, the GUI may display a notification of the likelihood of a condition of emotional or mental distress based on temperature deviations from a prenatal, perinatal, or postnatal baseline of the user. In some cases, the GUI may display a notification of the likelihood of a condition of emotional or mental distress based on sleep data deviations from a normal baseline, breath rate deviations from a normal baseline, heart rate variability (HRV) from a normal baseline, or a combination thereof. Based on the early detection (e.g., before the user experiences symptoms), a user may take early steps that may help reduce the severity of upcoming symptoms associated with the conditions of emotional or mental distress or limit the risk of having conditions of emotional or mental distress altogether.

[0026] Aspects of the disclosure are initially described in the context of systems supporting physiological data collection from users via wearable devices. Additional aspects of the disclosure are described in the context of an example GUI. Aspects of the disclosure are further illustrated by and described with reference to apparatus diagrams, system diagrams, and flowcharts that relate to conditions of emotional or mental distress identification and prediction from wearable-based physiological data.

[0027] FIG. **1** illustrates an example of a system **100** that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure. The system **100** includes a plurality of electronic devices (e.g., wearable devices **104**, user devices **106**) that may be worn and/or operated by one or more users **102**. The system **100** further includes a network **108** and one or more servers **110**.

[0028] The electronic devices may include any electronic devices known in the art, including wearable devices **104** (e.g., ring wearable devices, watch wearable devices, etc.), user devices **106** (e.g., smartphones, laptops, tablets). The electronic devices associated with the respective users **102** may include one or more of the following functionalities: 1) measuring physiological data, 2) storing the measured data, 3) processing the data, 4) providing outputs (e.g., via GUIs) to a user **102** based on the processed data, and 5) communicating data with one another and/or other computing devices. Different electronic devices may perform one or more of the functionalities.

[0029] Example wearable devices **104** may include wearable computing devices, such as a ring computing device (hereinafter "ring") configured to be worn on a user's **102** finger, a wrist computing device (e.g., a smart watch, fitness band, or bracelet) configured to be worn on a user's **102** wrist, and/or a head mounted computing device (e.g., glasses/goggles). Wearable devices **104** may also include bands, straps (e.g., flexible or inflexible bands or straps), stick-on sensors, and the like, that may be positioned in other locations, such as bands around the head (e.g., a forehead headband), arm (e.g., a forearm band and/or bicep band), and/or leg (e.g., a thigh or calf band), behind the ear, under the armpit, and the like. Wearable devices **104** may also be attached to, or included in, articles of clothing. For example, wearable devices **104** may be included in pockets and/or pouches on clothing. As another example, wearable device **104** may be clipped and/or pinned to clothing, or may otherwise be maintained within the vicinity of the user **102**. Example articles of clothing may include, but are not limited to, hats, shirts, gloves, pants, socks, outerwear (e.g., jackets), and undergarments. In some implementations, wearable devices **104** may be included with other types of devices such as training/sporting devices that are used during physical activity. For example, wearable devices **104** may be attached to, or included in, a bicycle, skis, a tennis racket, a golf club, and/or training weights.

[0030] Much of the present disclosure may be described in the context of a ring wearable device **104**. Accordingly, the terms "ring **104**," "wearable device **104**," and like terms, may be used interchangeably, unless noted otherwise herein. However, the use of the term "ring **104**" is not to be regarded as limiting, as it is contemplated herein that aspects of the present disclosure may be performed using other wearable devices (e.g., watch wearable devices, necklace wearable device, bracelet wearable devices, earring wearable devices, anklet wearable devices, and the like).

[0031] In some aspects, user devices **106** may include handheld mobile computing devices, such as smartphones and tablet computing devices. User devices **106** may also include personal computers, such as laptop and desktop computing devices. Other example user devices **106** may include server computing devices that may communicate with other electronic devices (e.g., via the Internet). In some implementations, computing devices may include medical devices, such as external wearable computing devices (e.g., Holter monitors). Medical devices may also include implantable medical devices, such as pacemakers and cardioverter defibrillators. Other example user devices **106** may include home computing devices, such as internet of things (IoT) devices (e.g., IoT devices), smart televisions, smart speakers, smart displays (e.g., video call displays), hubs (e.g., wireless communication hubs), security systems, smart appliances (e.g., thermostats and refrigerators), and fitness equipment.

[0032] Some electronic devices (e.g., wearable devices **104**, user devices **106**) may measure physiological parameters of respective users **102**, such as photoplethysmography waveforms, continuous skin temperature, a pulse waveform, respiration rate, heart rate, HRV, actigraphy, galvanic skin response, pulse oximetry, and/or other physiological parameters. Some electronic devices that measure physiological parameters may also perform some/all of the calculations described herein. Some electronic devices may not measure physiological parameters, but may perform some/all of the calculations described herein. For example, a ring (e.g., wearable device **104**), mobile device application, or a server computing device may process received physiological data that was measured by other devices.

[0033] In some implementations, a user **102** may operate, or may be associated with, multiple electronic devices, some of which may measure physiological parameters and some of which may process the measured physiological parameters. In some implementations, a user **102** may have a ring (e.g., wearable device **104**) that measures physiological parameters. The user **102** may also have, or be associated with, a user device **106** (e.g., mobile device, smartphone), where the wearable device **104** and the user device **106** are

communicatively coupled to one another. In some cases, the user device **106** may receive data from the wearable device **104** and perform some/all of the calculations described herein. In some implementations, the user device **106** may also measure physiological parameters described herein, such as motion/activity parameters.

[0034] For example, as illustrated in FIG. **1**, a first user **102**-*a* (User **1**) may operate, or may be associated with, a wearable device **104**-*a* (e.g., ring **104**-*a*) and a user device **106**-*a* that may operate as described herein. In this example, the user device **106**-*a* associated with user **102**-*a* may process/store physiological parameters measured by the ring **104**-*a*. Comparatively, a second user **102**-*b* (User **2**) may be associated with a ring **104**-*b*, a watch wearable device **104**-*c* (e.g., watch **104**-*c*), and a user device **106**-*b*, where the user device **106**-*b* associated with user **102**-*b* may process/store physiological parameters measured by the ring **104**-*b* and/or the watch **104**-*c*. Moreover, an nth user **102**-*n* (User N) may be associated with an arrangement of electronic devices described herein (e.g., ring **104**-*n*, user device **106**-*n*). In some aspects, wearable devices **104** (e.g., rings **104**, watches **104**) and other electronic devices may be communicatively coupled to the user devices **106** of the respective users **102** via Bluetooth, Wi-Fi, and other wireless protocols.

[0035] In some implementations, the rings **104** (e.g., wearable devices **104**) of the system **100** may be configured to collect physiological data from the respective users **102** based on arterial blood flow within the user's finger. In particular, a ring **104** may utilize one or more LEDs (e.g., red LEDs, green LEDs) that emit light on the palm-side of a user's finger to collect physiological data based on arterial blood flow within the user's finger. In some cases, the system **100** may be configured to collect physiological data from the respective users **102** based on blood flow diffused into a microvascular bed of skin with capillaries and arterioles. For example, the system **100** may collect PPG data based on a measured amount of blood diffused into the microvascular system of capillaries and arterioles. In some implementations, the ring **104** may acquire the physiological data using a combination of both green and red LEDs. The physiological data may include any physiological data known in the art including, but not limited to, temperature data, accelerometer data (e.g., movement/motion data), heart rate data, HRV data, blood oxygen level data, or any combination thereof.

[0036] The use of both green and red LEDs may provide several advantages over other solutions, as red and green LEDs have been found to have their own distinct advantages when acquiring physiological data under different conditions (e.g., light/dark, active/inactive) and via different parts of the body, and the like. For example, green LEDs have been found to exhibit better performance during exercise. Moreover, using multiple LEDs (e.g., green and red LEDs) distributed around the ring **104** has been found to exhibit superior performance as compared to wearable devices that utilize LEDs that are positioned close to one another, such as within a watch wearable device. Furthermore, the blood vessels in the finger (e.g., arteries, capillaries) are more accessible via LEDs as compared to blood vessels in the wrist. In particular, arteries in the wrist are positioned on the bottom of the wrist (e.g., palm-side of the wrist), meaning only capillaries are accessible on the top of the wrist (e.g., back of hand side of the wrist), where wearable watch devices and similar devices are typically worn. As such, utilizing LEDs and other sensors within a ring **104** has been found to exhibit superior performance as compared to wearable devices worn on the wrist, as the ring **104** may have greater access to arteries (as compared to capillaries), thereby resulting in stronger signals and more valuable physiological data.

[0037] The electronic devices of the system **100** (e.g., user devices **106**, wearable devices **104**) may be communicatively coupled to one or more servers **110** via wired or wireless communication protocols. For example, as shown in FIG. **1**, the electronic devices (e.g., user devices **106**) may be communicatively coupled to one or more servers **110** via a network **108**. The network **108** may implement transfer control protocol and internet protocol (TCP/IP), such as the Internet, or may implement other network **108** protocols. Network connections between the network **108** and the respective electronic devices may facilitate transport of data via email, web, text messages, mail, or any other appropriate form of interaction within a computer network **108**. For example, in some implementations, the ring **104**-*a* associated with the first user **102**-*a* may be communicatively coupled to the user device **106**-*a*, where the user device **106**-*a* is communicatively coupled to the servers **110** via the network **108**. In additional or alternative cases, wearable devices **104** (e.g., rings **104**, watches **104**) may be directly communicatively coupled to the network **108**.

[0038] The system **100** may offer an on-demand database service between the user devices **106** and the one or more servers **110**. In some cases, the servers **110** may receive data from the user devices **106** via the network **108**, and may store and analyze the data. Similarly, the servers **110** may provide data to the user devices **106** via the network **108**. In some cases, the servers **110** may be located at one or more data centers. The servers **110** may be used for data storage, management, and processing. In some implementations, the servers **110** may provide a web-based interface to the user device **106** via web browsers.

[0039] In some aspects, the system **100** may detect periods of time that a user **102** is asleep, and classify periods of time that the user **102** is asleep into one or more sleep stages (e.g., sleep stage classification). For example, as shown in FIG. **1**, User **102**-*a* may be associated with a wearable device **104**-*a* (e.g., ring **104**-*a*) and a user device **106**-*a*. In this example, the ring **104**-*a* may collect physiological data associated with the user **102**-*a*, including temperature, heart rate, HRV, respiratory rate, and the like. In some aspects, data collected by the ring **104**-*a* may be input to a machine learning classifier, where the machine learning classifier is configured to determine periods of time that the user **102**-*a* is (or was) asleep. Moreover, the machine learning classifier may be configured to classify periods of time into different sleep stages, including an awake sleep stage, a rapid eye movement (REM) sleep stage, a light sleep stage (non-REM (NREM)), and a deep sleep stage (NREM). In some aspects, the classified sleep stages may be displayed to the user **102**-*a* via a GUI of the user device **106**-*a*. Sleep stage classification may be used to provide feedback to a user **102**-*a* regarding the user's sleeping patterns, such as recommended bedtimes, recommended wake-up times, and the like. Moreover, in some implementations, sleep stage classification techniques described herein may be used to calculate scores for the respective user, such as Sleep Scores, Readiness Scores, and the like.

[0040] In some aspects, the system **100** may utilize circadian rhythm-derived features to further improve physiological data collection, data processing procedures, and other techniques described herein. The term circadian rhythm may refer to a natural, internal process that regulates an individual's sleep-wake cycle, that repeats approximately every 24 hours. In this regard, techniques described herein may utilize circadian rhythm adjustment models to improve physiological data collection, analysis, and data processing. For example, a circadian rhythm adjustment model may be input into a machine learning classifier along with physiological data collected from the user **102**-*a* via the wearable device **104**-*a*. In this example, the circadian rhythm adjustment model may be configured to "weight," or adjust, physiological data collected throughout a user's natural, approximately 24-hour circadian rhythm. In some implementations, the system may initially start with a "baseline" circadian rhythm adjustment model, and may modify the baseline model using physiological data collected from each user **102** to generate tailored, individualized circadian rhythm adjustment models that are specific to each respective user **102**.

[0041] In some aspects, the system **100** may utilize other biological rhythms to further improve physiological data collection, analysis, and processing by phase of these other rhythms. For example, if a weekly rhythm is detected within an individual's baseline data, then the model may be configured to adjust "weights" of data by day of the week. Biological rhythms that may require adjustment to the model by this method include: 1) ultradian (faster than a day rhythms, including sleep cycles in a sleep state, and oscillations from less than an hour to several hours periodicity in the measured physiological variables during wake state; 2) circadian rhythms; 3) non-endogenous daily rhythms shown to be imposed on top of circadian rhythms, as in work schedules; 4) weekly rhythms, or other artificial time periodicities exogenously imposed (e.g., in a hypothetical culture with 12 day "weeks", 12 day rhythms could be used); 5) multi-day ovarian rhythms in women and spermatogenesis rhythms in men; 6) lunar rhythms (relevant for individuals living with low or no artificial lights); and 7) seasonal rhythms.

[0042] The biological rhythms are not always stationary rhythms. For example, many women experience variability in ovarian cycle length across cycles, and ultradian rhythms are not expected to occur at exactly the same time or periodicity across days even within a user. As such, signal processing techniques sufficient to quantify the frequency composition while preserving temporal resolution of these rhythms in physiological data may be used to improve detection of these rhythms, to assign phase of each rhythm to each moment in time measured, and to thereby modify adjustment models and comparisons of time intervals. The biological rhythm-adjustment models and parameters can be added in linear or non-linear combinations as appropriate to more accurately capture the dynamic physiological baselines of an individual or group of individuals.

[0043] In some aspects, the respective devices of the system **100** may support techniques for prenatal, perinatal, or postnatal mental or emotional distress identification and prediction based on data collected by a wearable device **104**. In particular, the system **100** illustrated in FIG. **1** may support techniques for detecting the indication of one or more conditions of mental or emotional distress of a user **102** during pregnancy, postpartum, or both, and causing a user device **106** corresponding to the user **102** to display the indication of the one or more conditions. The indication of one or more conditions of mental or emotional distress may be an example of detecting that the one or more conditions of mental or emotional distress have already happened, detecting that the one or more conditions of mental or emotional distress are currently happening, and/or that the one or more conditions of mental or emotional distress are predicted to occur in the future. The one or more conditions of mental or emotional distress may include stress during pregnancy, stress during postpartum, postpartum anxiety, postpartum obsessive-compulsive disorder, postpartum panic disorder, postpartum post-traumatic stress disorder, postpartum psychosis, postpartum depression, or any combination thereof.

[0044] For example, as shown in FIG. **1**, User **1** (user **102**-*a*) may be associated with a wearable device **104**-*a* (e.g., ring **104**-*a*) and a user device **106**-*a*. In this example, the ring **104**-*a* may collect data associated with the user **102**-*a*, including temperature, sleep data, heart rate, HRV, respiratory rate, and the like. In some aspects, data collected by the ring **104**-*a* may be used to detect the indication of the one or more conditions of mental or emotional distress that User **1** experiences a health condition, a state of distress, or a problem with the prenatal, perinatal, or postnatal period of pregnancy. Identifying and/or predicting the one or more conditions of mental or emotional distress may be performed by any of the components of the system **100**, including the ring **104**-*a*, the user device **106**-*a* associated with User **1**, the one or more servers **110**, or any combination thereof. Upon identifying and/or predicting the one or more conditions of mental or emotional distress, the system **100** may selectively cause the GUI of the user device **106** to display the indication of the one or more conditions of mental or emotional distress. In such cases, the user device **106** may be associated with User **1**, User **2**, User N, or a combination thereof where User **2** and User N may be an example of a clinician, a caregiver, a user associated with User **1**, or a combination thereof.

[0045] In some implementations, upon receiving physiological data (e.g., including temperature data), the system **100** may determine a time series of temperature values taken over a plurality of days. The system **100** may identify that the temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user. As described in more detail herein, a prenatal, perinatal, or postnatal baseline may refer to a baseline or average temperature, or usual temperature variations for the user as measured throughout pregnancy, a postpartum period, or specific phases of pregnancy and/or postpartum, that may differ from the user's normal or non-pregnant baselines. In such cases, the system **100** may detect the indication of the one or more conditions of mental or emotional distress of the user based on identifying that the temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user.

[0046] In some implementations, the system **100** may generate alerts, messages, or recommendations for User **1**, User, **2**, and/or User N (e.g., via the ring **104**-*a*, user device **106**-*a*, or both) based on the detected indication of one or more conditions of mental or emotional distress, where the messages may provide insights regarding the detected indication of one or more conditions of mental or emotional

distress, such as a timing of the one or more conditions of mental or emotional distress. In some cases, the messages may provide insight regarding symptoms associated with the one or more conditions of mental or emotional distress, educational videos and/or text (e.g., content) associated with the one or more conditions of mental or emotional distress, recommendations to improve symptoms associated with the one or more conditions of mental or emotional distress, or a combination thereof.

[0047] It should be appreciated by a person skilled in the art that one or more aspects of the disclosure may be implemented in a system **100** to additionally or alternatively solve other problems than those described above. Furthermore, aspects of the disclosure may provide technical improvements to "conventional" systems or processes as described herein. However, the description and appended drawings only include example technical improvements resulting from implementing aspects of the disclosure, and accordingly do not represent all of the technical improvements provided within the scope of the claims.

[0048] FIG. **2** illustrates an example of a system **200** that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure. The system **200** may implement, or be implemented by, system **100**. In particular, system **200** illustrates an example of a ring **104** (e.g., wearable device **104**), a user device **106**, and a server **110**, as described with reference to FIG. **1**.

[0049] In some aspects, the ring **104** may be configured to be worn around a user's finger, and may determine one or more user physiological parameters when worn around the user's finger. Example measurements and determinations may include, but are not limited to, user skin temperature, pulse waveforms, respiratory rate, heart rate, HRV, blood oxygen levels, and the like.

[0050] The system **200** further includes a user device **106** (e.g., a smartphone) in communication with the ring **104**. For example, the ring **104** may be in wireless and/or wired communication with the user device **106**. In some implementations, the ring **104** may send measured and processed data (e.g., temperature data, PPG data, motion/accelerometer data, ring input data, and the like) to the user device **106**. The user device **106** may also send data to the ring **104**, such as ring **104** firmware/configuration updates. The user device **106** may process data. In some implementations, the user device **106** may transmit data to the server **110** for processing and/or storage.

[0051] The ring **104** may include a housing **205** that may include an inner housing **205**-*a* and an outer housing **205**-*b*. In some aspects, the housing **205** of the ring **104** may store or otherwise include various components of the ring including, but not limited to, device electronics, a power source (e.g., battery **210**, and/or capacitor), one or more substrates (e.g., printable circuit boards) that interconnect the device electronics and/or power source, and the like. The device electronics may include device modules (e.g., hardware/software), such as: a processing module **230**-*a*, a memory **215**, a communication module **220**-*a*, a power module **225**, and the like. The device electronics may also include one or more sensors. Example sensors may include one or more temperature sensors **240**, a PPG sensor assembly (e.g., PPG system **235**), and one or more motion sensors **245**.

[0052] The sensors may include associated modules (not illustrated) configured to communicate with the respective components/modules of the ring **104**, and generate signals associated with the respective sensors. In some aspects, each of the components/modules of the ring **104** may be communicatively coupled to one another via wired or wireless connections. Moreover, the ring **104** may include additional and/or alternative sensors or other components that are configured to collect physiological data from the user, including light sensors (e.g., LEDs), oximeters, and the like.

[0053] The ring **104** shown and described with reference to FIG. **2** is provided solely for illustrative purposes. As such, the ring **104** may include additional or alternative components as those illustrated in FIG. **2**. Other rings **104** that provide functionality described herein may be fabricated. For example, rings **104** with fewer components (e.g., sensors) may be fabricated. In a specific example, a ring **104** with a single temperature sensor **240** (or other sensor), a power source, and device electronics configured to read the single temperature sensor **240** (or other sensor) may be fabricated. In another specific example, a temperature sensor **240** (or other sensor) may be attached to a user's finger (e.g., using a clamps, spring loaded clamps, etc.). In this case, the sensor may be wired to another computing device, such as a wrist worn computing device that reads the temperature sensor **240** (or other sensor). In other examples, a ring **104** that includes additional sensors and processing functionality may be fabricated.

[0054] The housing **205** may include one or more housing **205** components. The housing **205** may include an outer housing **205**-*b* component (e.g., a shell) and an inner housing **205**-*a* component (e.g., a molding). The housing **205** may include additional components (e.g., additional layers) not explicitly illustrated in FIG. **2**. For example, in some implementations, the ring **104** may include one or more insulating layers that electrically insulate the device electronics and other conductive materials (e.g., electrical traces) from the outer housing **205**-*b* (e.g., a metal outer housing **205**-*b*). The housing **205** may provide structural support for the device electronics, battery **210**, substrate(s), and other components. For example, the housing **205** may protect the device electronics, battery **210**, and substrate(s) from mechanical forces, such as pressure and impacts. The housing **205** may also protect the device electronics, battery **210**, and substrate(s) from water and/or other chemicals.

[0055] The outer housing **205**-*b* may be fabricated from one or more materials. In some implementations, the outer housing **205**-*b* may include a metal, such as titanium, that may provide strength and abrasion resistance at a relatively light weight. The outer housing **205**-*b* may also be fabricated from other materials, such polymers. In some implementations, the outer housing **205**-*b* may be protective as well as decorative.

[0056] The inner housing **205**-*a* may be configured to interface with the user's finger. The inner housing **205**-*a* may be formed from a polymer (e.g., a medical grade polymer) or other material. In some implementations, the inner housing **205**-*a* may be transparent. For example, the inner housing **205**-*a* may be transparent to light emitted by the PPG light emitting diodes (LEDs). In some implementations, the inner housing **205**-*a* component may be molded onto the outer housing **205**-*b*. For example, the inner hous-

ing **205**-*a* may include a polymer that is molded (e.g., injection molded) to fit into an outer housing **205**-*b* metallic shell.

[0057] The ring **104** may include one or more substrates (not illustrated). The device electronics and battery **210** may be included on the one or more substrates. For example, the device electronics and battery **210** may be mounted on one or more substrates. Example substrates may include one or more printed circuit boards (PCBs), such as flexible PCB (e.g., polyimide). In some implementations, the electronics/battery **210** may include surface mounted devices (e.g., surface-mount technology (SMT) devices) on a flexible PCB. In some implementations, the one or more substrates (e.g., one or more flexible PCBs) may include electrical traces that provide electrical communication between device electronics. The electrical traces may also connect the battery **210** to the device electronics.

[0058] The device electronics, battery **210**, and substrates may be arranged in the ring **104** in a variety of ways. In some implementations, one substrate that includes device electronics may be mounted along the bottom of the ring **104** (e.g., the bottom half), such that the sensors (e.g., PPG system **235**, temperature sensors **240**, motion sensors **245**, and other sensors) interface with the underside of the user's finger. In these implementations, the battery **210** may be included along the top portion of the ring **104** (e.g., on another substrate).

[0059] The various components/modules of the ring **104** represent functionality (e.g., circuits and other components) that may be included in the ring **104**. Modules may include any discrete and/or integrated electronic circuit components that implement analog and/or digital circuits capable of producing the functions attributed to the modules herein. For example, the modules may include analog circuits (e.g., amplification circuits, filtering circuits, analog/digital conversion circuits, and/or other signal conditioning circuits). The modules may also include digital circuits (e.g., combinational or sequential logic circuits, memory circuits etc.).

[0060] The memory **215** (memory module) of the ring **104** may include any volatile, non-volatile, magnetic, or electrical media, such as a random access memory (RAM), read-only memory (ROM), non-volatile RAM (NVRAM), electrically-erasable programmable ROM (EEPROM), flash memory, or any other memory device. The memory **215** may store any of the data described herein. For example, the memory **215** may be configured to store data (e.g., motion data, temperature data, PPG data) collected by the respective sensors and PPG system **235**. Furthermore, memory **215** may include instructions that, when executed by one or more processing circuits, cause the modules to perform various functions attributed to the modules herein. The device electronics of the ring **104** described herein are only example device electronics. As such, the types of electronic components used to implement the device electronics may vary based on design considerations.

[0061] The functions attributed to the modules of the ring **104** described herein may be embodied as one or more processors, hardware, firmware, software, or any combination thereof. Depiction of different features as modules is intended to highlight different functional aspects and does not necessarily imply that such modules must be realized by separate hardware/software components. Rather, functionality associated with one or more modules may be performed by separate hardware/software components or integrated within common hardware/software components.

[0062] The processing module **230**-*a* of the ring **104** may include one or more processors (e.g., processing units), microcontrollers, digital signal processors, systems on a chip (SOCs), and/or other processing devices. The processing module **230**-*a* communicates with the modules included in the ring **104**. For example, the processing module **230**-*a* may transmit/receive data to/from the modules and other components of the ring **104**, such as the sensors. As described herein, the modules may be implemented by various circuit components. Accordingly, the modules may also be referred to as circuits (e.g., a communication circuit and power circuit).

[0063] The processing module **230**-*a* may communicate with the memory **215**. The memory **215** may include computer-readable instructions that, when executed by the processing module **230**-*a*, cause the processing module **230**-*a* to perform the various functions attributed to the processing module **230**-*a* herein. In some implementations, the processing module **230**-*a* (e.g., a microcontroller) may include additional features associated with other modules, such as communication functionality provided by the communication module **220**-*a* (e.g., an integrated Bluetooth Low Energy transceiver) and/or additional onboard memory **215**.

[0064] The communication module **220**-*a* may include circuits that provide wireless and/or wired communication with the user device **106** (e.g., communication module **220**-*b* of the user device **106**). In some implementations, the communication modules **220**-*a*, **220**-*b* may include wireless communication circuits, such as Bluetooth circuits and/or Wi-Fi circuits. In some implementations, the communication modules **220**-*a*, **220**-*b* can include wired communication circuits, such as Universal Serial Bus (USB) communication circuits. Using the communication module **220**-*a*, the ring **104** and the user device **106** may be configured to communicate with each other. The processing module **230**-*a* of the ring may be configured to transmit/receive data to/from the user device **106** via the communication module **220**-*a*. Example data may include, but is not limited to, motion data, temperature data, pulse waveforms, heart rate data, HRV data, PPG data, and status updates (e.g., charging status, battery charge level, and/or ring **104** configuration settings). The processing module **230**-*a* of the ring may also be configured to receive updates (e.g., software/firmware updates) and data from the user device **106**.

[0065] The ring **104** may include a battery **210** (e.g., a rechargeable battery **210**). An example battery **210** may include a Lithium-Ion or Lithium-Polymer type battery **210**, although a variety of battery **210** options are possible. The battery **210** may be wirelessly charged. In some implementations, the ring **104** may include a power source other than the battery **210**, such as a capacitor. The power source (e.g., battery **210** or capacitor) may have a curved geometry that matches the curve of the ring **104**. In some aspects, a charger or other power source may include additional sensors that may be used to collect data in addition to, or that supplements, data collected by the ring **104** itself. Moreover, a charger or other power source for the ring **104** may function as a user device **106**, in which case the charger or other power source for the ring **104** may be configured to receive data from the ring **104**, store and/or process data received from the ring **104**, and communicate data between the ring **104** and the servers **110**.

[0066] In some aspects, the ring **104** includes a power module **225** that may control charging of the battery **210**. For example, the power module **225** may interface with an external wireless charger that charges the battery **210** when interfaced with the ring **104**. The charger may include a datum structure that mates with a ring **104** datum structure to create a specified orientation with the ring **104** during charging. The power module **225** may also regulate voltage (s) of the device electronics, regulate power output to the device electronics, and monitor the state of charge of the battery **210**. In some implementations, the battery **210** may include a protection circuit module (PCM) that protects the battery **210** from high current discharge, over voltage during charging, and under voltage during discharge. The power module **225** may also include electro-static discharge (ESD) protection.

[0067] The one or more temperature sensors **240** may be electrically coupled to the processing module **230**-*a*. The temperature sensor **240** may be configured to generate a temperature signal (e.g., temperature data) that indicates a temperature read or sensed by the temperature sensor **240**. The processing module **230**-*a* may determine a temperature of the user in the location of the temperature sensor **240**. For example, in the ring **104**, temperature data generated by the temperature sensor **240** may indicate a temperature of a user at the user's finger (e.g., skin temperature). In some implementations, the temperature sensor **240** may contact the user's skin. In other implementations, a portion of the housing **205** (e.g., the inner housing **205**-*a*) may form a barrier (e.g., a thin, thermally conductive barrier) between the temperature sensor **240** and the user's skin. In some implementations, portions of the ring **104** configured to contact the user's finger may have thermally conductive portions and thermally insulative portions. The thermally conductive portions may conduct heat from the user's finger to the temperature sensors **240**. The thermally insulative portions may insulate portions of the ring **104** (e.g., the temperature sensor **240**) from ambient temperature.

[0068] In some implementations, the temperature sensor **240** may generate a digital signal (e.g., temperature data) that the processing module **230**-*a* may use to determine the temperature. As another example, in cases where the temperature sensor **240** includes a passive sensor, the processing module **230**-*a* (or a temperature sensor **240** module) may measure a current/voltage generated by the temperature sensor **240** and determine the temperature based on the measured current/voltage. Example temperature sensors **240** may include a thermistor, such as a negative temperature coefficient (NTC) thermistor, or other types of sensors including resistors, transistors, diodes, and/or other electrical/electronic components.

[0069] The processing module **230**-*a* may sample the user's temperature over time. For example, the processing module **230**-*a* may sample the user's temperature according to a sampling rate. An example sampling rate may include one sample per second, although the processing module **230**-*a* may be configured to sample the temperature signal at other sampling rates that are higher or lower than one sample per second. In some implementations, the processing module **230**-*a* may sample the user's temperature continuously throughout the day and night. Sampling at a sufficient rate (e.g., one sample per second) throughout the day may provide sufficient temperature data for analysis described herein.

[0070] The processing module **230**-*a* may store the sampled temperature data in memory **215**. In some implementations, the processing module **230**-*a* may process the sampled temperature data. For example, the processing module **230**-*a* may determine average temperature values over a period of time. In one example, the processing module **230**-*a* may determine an average temperature value each minute by summing all temperature values collected over the minute and dividing by the number of samples over the minute. In a specific example where the temperature is sampled at one sample per second, the average temperature may be a sum of all sampled temperatures for one minute divided by sixty seconds. The memory **215** may store the average temperature values over time. In some implementations, the memory **215** may store average temperatures (e.g., one per minute) instead of sampled temperatures in order to conserve memory **215**.

[0071] The sampling rate, that may be stored in memory **215**, may be configurable. In some implementations, the sampling rate may be the same throughout the day and night. In other implementations, the sampling rate may be changed throughout the day/night. In some implementations, the ring **104** may filter/reject temperature readings, such as large spikes in temperature that are not indicative of physiological changes (e.g., a temperature spike from a hot shower). In some implementations, the ring **104** may filter/reject temperature readings that may not be reliable due to other factors, such as excessive motion during exercise (e.g., as indicated by a motion sensor **245**).

[0072] The ring **104** (e.g., communication module) may transmit the sampled and/or average temperature data to the user device **106** for storage and/or further processing. The user device **106** may transfer the sampled and/or average temperature data to the server **110** for storage and/or further processing.

[0073] Although the ring **104** is illustrated as including a single temperature sensor **240**, the ring **104** may include multiple temperature sensors **240** in one or more locations, such as arranged along the inner housing **205**-*a* near the user's finger. In some implementations, the temperature sensors **240** may be stand-alone temperature sensors **240**. Additionally, or alternatively, one or more temperature sensors **240** may be included with other components (e.g., packaged with other components), such as with the accelerometer and/or processor.

[0074] The processing module **230**-*a* may acquire and process data from multiple temperature sensors **240** in a similar manner described with respect to a single temperature sensor **240**. For example, the processing module **230** may individually sample, average, and store temperature data from each of the multiple temperature sensors **240**. In other examples, the processing module **230**-*a* may sample the sensors at different rates and average/store different values for the different sensors. In some implementations, the processing module **230**-*a* may be configured to determine a single temperature based on the average of two or more temperatures determined by two or more temperature sensors **240** in different locations on the finger.

[0075] The temperature sensors **240** on the ring **104** may acquire distal temperatures at the user's finger (e.g., any finger). For example, one or more temperature sensors **240** on the ring **104** may acquire a user's temperature from the underside of a finger or at a different location on the finger. In some implementations, the ring **104** may continuously

acquire distal temperature (e.g., at a sampling rate). Although distal temperature measured by a ring **104** at the finger is described herein, other devices may measure temperature at the same/different locations. In some cases, the distal temperature measured at a user's finger may differ from the temperature measured at a user's wrist or other external body location. Additionally, the distal temperature measured at a user's finger (e.g., a "shell" temperature) may differ from the user's core temperature. As such, the ring **104** may provide a useful temperature signal that may not be acquired at other internal/external locations of the body. In some cases, continuous temperature measurement at the finger may capture temperature fluctuations (e.g., small or large fluctuations) that may not be evident in core temperature. For example, continuous temperature measurement at the finger may capture minute-to-minute or hour-to-hour temperature fluctuations that provide additional insight that may not be provided by other temperature measurements elsewhere in the body.

[0076] The ring **104** may include a PPG system **235**. The PPG system **235** may include one or more optical transmitters that transmit light. The PPG system **235** may also include one or more optical receivers that receive light transmitted by the one or more optical transmitters. An optical receiver may generate a signal (hereinafter "PPG" signal) that indicates an amount of light received by the optical receiver. The optical transmitters may illuminate a region of the user's finger. The PPG signal generated by the PPG system **235** may indicate the perfusion of blood in the illuminated region. For example, the PPG signal may indicate blood volume changes in the illuminated region caused by a user's pulse pressure. The processing module **230**-*a* may sample the PPG signal and determine a user's pulse waveform based on the PPG signal. The processing module **230**-*a* may determine a variety of physiological parameters based on the user's pulse waveform, such as a user's respiratory rate, heart rate, HRV, oxygen saturation, and other circulatory parameters.

[0077] In some implementations, the PPG system **235** may be configured as a reflective PPG system **235** where the optical receiver(s) receive transmitted light that is reflected through the region of the user's finger. In some implementations, the PPG system **235** may be configured as a transmissive PPG system **235** where the optical transmitter(s) and optical receiver(s) are arranged opposite to one another, such that light is transmitted directly through a portion of the user's finger to the optical receiver(s).

[0078] The number and ratio of transmitters and receivers included in the PPG system **235** may vary. Example optical transmitters may include light-emitting diodes (LEDs). The optical transmitters may transmit light in the infrared spectrum and/or other spectrums. Example optical receivers may include, but are not limited to, photosensors, phototransistors, and photodiodes. The optical receivers may be configured to generate PPG signals in response to the wavelengths received from the optical transmitters. The location of the transmitters and receivers may vary. Additionally, a single device may include reflective and/or transmissive PPG systems **235**.

[0079] The PPG system **235** illustrated in FIG. **2** may include a reflective PPG system **235** in some implementations. In these implementations, the PPG system **235** may include a centrally located optical receiver (e.g., at the bottom of the ring **104**) and two optical transmitters located on each side of the optical receiver. In this implementation, the PPG system **235** (e.g., optical receiver) may generate the PPG signal based on light received from one or both of the optical transmitters. In other implementations, other placements, combinations, and/or configurations of one or more optical transmitters and/or optical receivers are contemplated.

[0080] The processing module **230**-*a* may control one or both of the optical transmitters to transmit light while sampling the PPG signal generated by the optical receiver. In some implementations, the processing module **230**-*a* may cause the optical transmitter with the stronger received signal to transmit light while sampling the PPG signal generated by the optical receiver. For example, the selected optical transmitter may continuously emit light while the PPG signal is sampled at a sampling rate (e.g., 250 Hz).

[0081] Sampling the PPG signal generated by the PPG system **235** may result in a pulse waveform that may be referred to as a "PPG." The pulse waveform may indicate blood pressure vs time for multiple cardiac cycles. The pulse waveform may include peaks that indicate cardiac cycles. Additionally, the pulse waveform may include respiratory induced variations that may be used to determine respiration rate. The processing module **230**-*a* may store the pulse waveform in memory **215** in some implementations. The processing module **230**-*a* may process the pulse waveform as it is generated and/or from memory **215** to determine user physiological parameters described herein.

[0082] The processing module **230**-*a* may determine the user's heart rate based on the pulse waveform. For example, the processing module **230**-*a* may determine heart rate (e.g., in beats per minute) based on the time between peaks in the pulse waveform. The time between peaks may be referred to as an interbeat interval (IBI). The processing module **230**-*a* may store the determined heart rate values and IBI values in memory **215**.

[0083] The processing module **230**-*a* may determine HRV over time. For example, the processing module **230**-*a* may determine HRV based on the variation in the IBIs. The processing module **230**-*a* may store the HRV values over time in the memory **215**. Moreover, the processing module **230**-*a* may determine the user's respiratory rate over time. For example, the processing module **230**-*a* may determine respiratory rate based on frequency modulation, amplitude modulation, or baseline modulation of the user's IBI values over a period of time. Respiratory rate may be calculated in breaths per minute or as another breathing rate (e.g., breaths per 30 seconds). The processing module **230**-*a* may store user respiratory rate values over time in the memory **215**.

[0084] The ring **104** may include one or more motion sensors **245**, such as one or more accelerometers (e.g., 6-D accelerometers) and/or one or more gyroscopes (gyros). The motion sensors **245** may generate motion signals that indicate motion of the sensors. For example, the ring **104** may include one or more accelerometers that generate acceleration signals that indicate acceleration of the accelerometers. As another example, the ring **104** may include one or more gyro sensors that generate gyro signals that indicate angular motion (e.g., angular velocity) and/or changes in orientation. The motion sensors **245** may be included in one or more sensor packages. An example accelerometer/gyro sensor is a Bosch BMI160 inertial micro electro-mechanical system (MEMS) sensor that may measure angular rates and accelerations in three perpendicular axes.

[0085] The processing module **230**-*a* may sample the motion signals at a sampling rate (e.g., 50 Hz) and determine the motion of the ring **104** based on the sampled motion signals. For example, the processing module **230**-*a* may sample acceleration signals to determine acceleration of the ring **104**. As another example, the processing module **230**-*a* may sample a gyro signal to determine angular motion. In some implementations, the processing module **230**-*a* may store motion data in memory **215**. Motion data may include sampled motion data as well as motion data that is calculated based on the sampled motion signals (e.g., acceleration and angular values).

[0086] The ring **104** may store a variety of data described herein. For example, the ring **104** may store temperature data, such as raw sampled temperature data and calculated temperature data (e.g., average temperatures). As another example, the ring **104** may store PPG signal data, such as pulse waveforms and data calculated based on the pulse waveforms (e.g., heart rate values, IBI values, HRV values, and respiratory rate values). The ring **104** may also store motion data, such as sampled motion data that indicates linear and angular motion.

[0087] The ring **104**, or other computing device, may calculate and store additional values based on the sampled/calculated physiological data. For example, the processing module **230** may calculate and store various metrics, such as sleep metrics (e.g., a Sleep Score), activity metrics, and Readiness metrics. In some implementations, additional values/metrics may be referred to as "derived values." The ring **104**, or other computing/wearable device, may calculate a variety of values/metrics with respect to motion. Example derived values for motion data may include, but are not limited to, motion count values, regularity values, intensity values, metabolic equivalence of task values (METs), and orientation values. Motion counts, regularity values, intensity values, and METs may indicate an amount of user motion (e.g., velocity/acceleration) over time. Orientation values may indicate how the ring **104** is oriented on the user's finger and if the ring **104** is worn on the left hand or right hand.

[0088] In some implementations, motion counts and regularity values may be determined by counting a number of acceleration peaks within one or more periods of time (e.g., one or more 30 second to 1 minute periods). Intensity values may indicate a number of movements and the associated intensity (e.g., acceleration values) of the movements. The intensity values may be categorized as low, medium, and high, depending on associated threshold acceleration values. METs may be determined based on the intensity of movements during a period of time (e.g., 30 seconds), the regularity/irregularity of the movements, and the number of movements associated with the different intensities.

[0089] In some implementations, the processing module **230**-*a* may compress the data stored in memory **215**. For example, the processing module **230**-*a* may delete sampled data after making calculations based on the sampled data. As another example, the processing module **230**-*a* may average data over longer periods of time in order to reduce the number of stored values. In a specific example, if average temperatures for a user over one minute are stored in memory **215**, the processing module **230**-*a* may calculate average temperatures over a five minute time period for storage, and then subsequently erase the one minute average temperature data. The processing module **230**-*a* may compress data based on a variety of factors, such as the total amount of used/available memory **215** and/or an elapsed time since the ring **104** last transmitted the data to the user device **106**.

[0090] Although a user's physiological parameters may be measured by sensors included on a ring **104**, other devices may measure a user's physiological parameters. For example, although a user's temperature may be measured by a temperature sensor **240** included in a ring **104**, other devices may measure a user's temperature. In some examples, other wearable devices (e.g., wrist devices) may include sensors that measure user physiological parameters. Additionally, medical devices, such as external medical devices (e.g., wearable medical devices) and/or implantable medical devices, may measure a user's physiological parameters. One or more sensors on any type of computing device may be used to implement the techniques described herein.

[0091] The physiological measurements may be taken continuously throughout the day and/or night. In some implementations, the physiological measurements may be taken during portions of the day and/or portions of the night. In some implementations, the physiological measurements may be taken in response to determining that the user is in a specific state, such as an active state, resting state, and/or a sleeping state. For example, the ring **104** can make physiological measurements in a resting/sleep state in order to acquire cleaner physiological signals. In one example, the ring **104** or other device/system may detect when a user is resting and/or sleeping and acquire physiological parameters (e.g., temperature) for that detected state. The devices/systems may use the resting/sleep physiological data and/or other data when the user is in other states in order to implement the techniques of the present disclosure.

[0092] In some implementations, as described previously herein, the ring **104** may be configured to collect, store, and/or process data, and may transfer any of the data described herein to the user device **106** for storage and/or processing. In some aspects, the user device **106** includes a wearable application **250**, an operating system (OS), a web browser application (e.g., web browser **280**), one or more additional applications, and a GUI **275**. The user device **106** may further include other modules and components, including sensors, audio devices, haptic feedback devices, and the like. The wearable application **250** may include an example of an application (e.g., "app") that may be installed on the user device **106**. The wearable application **250** may be configured to acquire data from the ring **104**, store the acquired data, and process the acquired data as described herein. For example, the wearable application **250** may include a user interface (UI) module **255**, an acquisition module **260**, a processing module **230**-*b*, a communication module **220**-*b*, and a storage module (e.g., database **265**) configured to store application data.

[0093] The various data processing operations described herein may be performed by the ring **104**, the user device **106**, the servers **110**, or any combination thereof. For example, in some cases, data collected by the ring **104** may be pre-processed and transmitted to the user device **106**. In this example, the user device **106** may perform some data processing operations on the received data, may transmit the data to the servers **110** for data processing, or both. For instance, in some cases, the user device **106** may perform processing operations that require relatively low processing power and/or operations that require a relatively low latency,

whereas the user device **106** may transmit the data to the servers **110** for processing operations that require relatively high processing power and/or operations that may allow relatively higher latency.

[0094] In some aspects, the ring **104**, user device **106**, and server **110** of the system **200** may be configured to evaluate sleep patterns for a user. In particular, the respective components of the system **200** may be used to collect data from a user via the ring **104**, and generate one or more scores (e.g., Sleep Score, Readiness Score) for the user based on the collected data. For example, as noted previously herein, the ring **104** of the system **200** may be worn by a user to collect data from the user, including temperature, heart rate, HRV, and the like. Data collected by the ring **104** may be used to determine when the user is asleep in order to evaluate the user's sleep for a given "sleep day." In some aspects, scores may be calculated for the user for each respective sleep day, such that a first sleep day is associated with a first set of scores, and a second sleep day is associated with a second set of scores. Scores may be calculated for each respective sleep day based on data collected by the ring **104** during the respective sleep day. Scores may include, but are not limited to, Sleep Scores, Readiness Scores, and the like.

[0095] In some cases, "sleep days" may align with the traditional calendar days, such that a given sleep day runs from midnight to midnight of the respective calendar day. In other cases, sleep days may be offset relative to calendar days. For example, sleep days may run from 6:00 pm (18:00) of a calendar day until 6:00 pm (18:00) of the subsequent calendar day. In this example, 6:00 pm may serve as a "cut-off time," where data collected from the user before 6:00 pm is counted for the current sleep day, and data collected from the user after 6:00 pm is counted for the subsequent sleep day. Due to the fact that most individuals sleep the most at night, offsetting sleep days relative to calendar days may enable the system **200** to evaluate sleep patterns for users in such a manner that is consistent with their sleep schedules. In some cases, users may be able to selectively adjust (e.g., via the GUI) a timing of sleep days relative to calendar days so that the sleep days are aligned with the duration of time that the respective users typically sleep.

[0096] In some implementations, each overall score for a user for each respective day (e.g., Sleep Score, Readiness Score) may be determined/calculated based on one or more "contributors," "factors," or "contributing factors." For example, a user's overall Sleep Score may be calculated based on a set of contributors, including: total sleep, efficiency, restfulness, REM sleep, deep sleep, latency, timing, or any combination thereof. The Sleep Score may include any quantity of contributors. The "total sleep" contributor may refer to the sum of all sleep periods of the sleep day. The "efficiency" contributor may reflect the percentage of time spent asleep compared to time spent awake while in bed, and may be calculated using the efficiency average of long sleep periods (e.g., primary sleep period) of the sleep day, weighted by a duration of each sleep period. The "restfulness" contributor may indicate how restful the user's sleep is, and may be calculated using the average of all sleep periods of the sleep day, weighted by a duration of each period. The restfulness contributor may be based on a "wake up count" (e.g., sum of all the wake-ups (when user wakes up) detected during different sleep periods), excessive movement, and a "got up count" (e.g., sum of all the got-ups (when user gets out of bed) detected during the different sleep periods).

[0097] The "REM sleep" contributor may refer to a sum total of REM sleep durations across all sleep periods of the sleep day including REM sleep. Similarly, the "deep sleep" contributor may refer to a sum total of deep sleep durations across all sleep periods of the sleep day including deep sleep. The "latency" contributor may signify how long (e.g., average, median, longest) the user takes to go to sleep, and may be calculated using the average of long sleep periods throughout the sleep day, weighted by a duration of each period and the number of such periods (e.g., consolidation of a given sleep stage or sleep stages may be its own contributor or weight other contributors). Lastly, the "timing" contributor may refer to a relative timing of sleep periods within the sleep day and/or calendar day, and may be calculated using the average of all sleep periods of the sleep day, weighted by a duration of each period.

[0098] By way of another example, a user's overall Readiness Score may be calculated based on a set of contributors, including: sleep, sleep balance, heart rate, HRV balance, recovery index, temperature, activity, activity balance, or any combination thereof. The Readiness Score may include any quantity of contributors. The "sleep" contributor may refer to the combined Sleep Score of all sleep periods within the sleep day. The "sleep balance" contributor may refer to a cumulative duration of all sleep periods within the sleep day. In particular, sleep balance may indicate to a user whether the sleep that the user has been getting over some duration of time (e.g., the past two weeks) is in balance with the user's needs. Typically, adults need 7-9 hours of sleep a night to stay healthy, alert, and to perform at their best both mentally and physically. However, it is normal to have an occasional night of bad sleep, so the sleep balance contributor takes into account long-term sleep patterns to determine whether each user's sleep needs are being met. The "resting heart rate" contributor may indicate a lowest heart rate from the longest sleep period of the sleep day (e.g., primary sleep period) and/or the lowest heart rate from naps occurring after the primary sleep period.

[0099] Continuing with reference to the "contributors" (e.g., factors, contributing factors) of the Readiness Score, the "HRV balance" contributor may indicate a highest HRV average from the primary sleep period and the naps happening after the primary sleep period. The HRV balance contributor may help users keep track of their recovery status by comparing their HRV trend over a first time period (e.g., two weeks) to an average HRV over some second, longer time period (e.g., three months). The "recovery index" contributor may be calculated based on the longest sleep period. Recovery index measures how long it takes for a user's resting heart rate to stabilize during the night. A sign of a very good recovery is that the user's resting heart rate stabilizes during the first half of the night, at least six hours before the user wakes up, leaving the body time to recover for the next day. The "body temperature" contributor may be calculated based on the longest sleep period (e.g., primary sleep period) or based on a nap happening after the longest sleep period if the user's highest temperature during the nap is at least higher than the highest temperature during the longest period. In some aspects, the ring may measure a user's body temperature while the user is asleep, and the system **200** may display the user's average temperature

relative to the user's baseline temperature. If a user's body temperature is outside of their normal range (e.g., clearly above or below 0.0), the body temperature contributor may be highlighted (e.g., go to a "Pay attention" state) or otherwise generate an alert for the user.

[0100] In some aspects, the system **200** may support techniques for prenatal, perinatal, or postnatal mental or emotional distress identification and prediction. In particular, the respective components of the system **200** may be used to detect the indication of the one or more conditions of mental or emotional distress based on identifying that the temperature values in a time series representing the user's temperature over time deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user. The indication of the one or more conditions of mental or emotional distress for the user may be identified and/or predicted by leveraging temperature sensors on the ring **104** of the system **200**. In some cases, the indication of the condition of mental or emotional distress may be estimated by identifying one or more morphological features such as deviations in the time series representing the user's temperature over time relative to the prenatal, perinatal, or postnatal baseline of temperature values and detecting the indication of one or more one or more conditions of mental or emotional distress that correspond to the deviations of the time series. The indication of one or more conditions of mental or emotional distress may be an example of identifying that the one or more conditions of mental or emotional distress have already occurred, are currently occurring, and/or that the one or more conditions of mental or emotional distress are predicted to occur in the future.

[0101] For example, as noted previously herein, the ring **104** of the system **200** may be worn by a user to collect data from the user, including temperature, sleep data, heart rate, HRV, respiratory data, and the like. The ring **104** of the system **200** may collect the physiological data from the user based on temperature sensors and measurements extracted from arterial blood flow (e.g., using PPG signals). In some cases, the ring **104** may collect the physiological data from the user based on measurements extracted from capillary blood flow, arteriole blood flow, or both. The physiological data may be collected continuously. In some implementations, the processing module **230**-*a* may sample the user's temperature continuously throughout the day and night. Sampling at a sufficient rate (e.g., one sample per minute) throughout the day and/or night may provide sufficient temperature data for analysis described herein. In some implementations, the ring **104** may continuously acquire temperature data (e.g., at a sampling rate). In some examples, even though temperature is collected continuously, the system **200** may leverage other information about the user that it has collected or otherwise derived (e.g., sleep stage, activity levels, illness onset, etc.) to select a representative temperature for a particular day that is an accurate representation of the underlying physiological phenomenon.

[0102] In contrast, systems that require a user to manually take their temperature each day and/or systems that measure temperature continuously but lack any other contextual information about the user may select inaccurate or inconsistent temperature values for their pregnancy and/or postpartum tracking, leading to inaccurate predictions and decreased user experience. In contrast, data collected by the ring **104** may be used to accurately detect the indication of the one or more conditions of mental or emotional distress of the user. Prenatal, perinatal, or postnatal mental or emotional distress identification and prediction and related techniques are further shown and described with reference to FIG. **3**.

[0103] FIG. **3** illustrates an example of a system **300** that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure. The system **300** may implement, or be implemented by, system **100**, system **200**, or both. In particular, system **300** illustrates an example of a ring **104** (e.g., wearable device **104**), a user device **106**, and a server **110**, as described with reference to FIG. **1**.

[0104] The ring **305** may acquire temperature data **320**, heart rate data **325**, respiratory rate data **330**, HRV data **335**, sleep data **340**, among other forms of physiological data as described herein. In such cases, the ring **305** may transmit temperature data **320**, heart rate data **325**, respiratory rate data **330**, HRV data **335**, and sleep data **340** to the user device **310**. The temperature data **320** may include continuous nighttime temperature data. The respiratory rate data **330** may include continuous nighttime breath rate data. In some cases, multiple devices may acquire physiological data. For example, a first computing device (e.g., user device **310**) and a second computing device (e.g., the ring **305**) may acquire temperature data **320**, heart rate data **325**, respiratory rate data **330**, HRV data **335**, sleep data **340**, or a combination thereof.

[0105] For example, the ring **305** may acquire user physiological data, such as user temperature data **320**, respiratory rate data **330**, heart rate data **325**, HRV data **335**, and sleep data **340**, SpO2 data, (e.g., blood oxygen saturation), galvanic skin response, actigraphy, and/or other user physiological data. For example, the ring **305** may acquire raw data and convert the raw data to features with daily granularity. In some implementations, different granularity input data may be used. The ring **305** may send the data to another computing device, such as a mobile device (e.g., user device **310**) for further processing.

[0106] For example, the user device **310** may identify and/or predict the indication of one or more conditions of mental or emotional distress based on the received data. In some cases, the system **300** may identify and/or predict the indication of the one or more conditions of mental or emotional distress based on temperature data **320**, respiratory rate data **330**, heart rate data **325**, HRV data **335**, sleep data **340** (e.g., sleep architecture), SpO2 data, galvanic skin response, activity, or a combination thereof. In some cases, the system **300** may determine which features are useful predictors for conditions of mental or emotional distress during the prenatal, perinatal, or postnatal period of pregnancy.

[0107] Although the system may be implemented by a ring **305** and a user device **310**, any combination of computing devices described herein may implement the features attributed to the system **300**. In some cases, the system may smooth the data (e.g., using a 7-day smoothing window or other window). The missing values may be imputed (e.g., using the forecaster Impute method from the python package).

[0108] The user device **310**-*a* may include a ring application **345**. The ring application **345** may include at least modules **350** and application data **355**. In some cases, the application data **355** may include historical temperature

patterns for the user and other data. The other data may include temperature data **320**, heart rate data **325**, respiratory rate data **330**, HRV data **335**, sleep data **340**, or a combination thereof.

[0109] The ring application **345** may present a predicted and/or detected one or more conditions of mental or emotional distress to the user. The ring application **345** may include an application data processing module that may perform data processing. For example, the application data processing module may include modules **350** that provide functions attributed to the system **300**. Example modules **350** may include a daily temperature determination module, a time series processing module, a conditions of mental or emotional distress identification module, and conditions of mental or emotional distress prediction module.

[0110] The daily temperature determination module may determine daily temperature values (e.g., by selecting a representative temperature value for that day from a series of temperature values that were collected continuously throughout the night). The time series processing module may process time series data to identify that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values. The mental or emotional distress identification module may identify the indication of the one or more conditions of mental or emotional distress of the user based on the processed time series data. The mental or emotional distress prediction module may predict the indication of the one or more conditions of mental or emotional distress of the user based on the processed time series data. In such cases, the system **300** may receive user physiological data (e.g., from a ring **305**) and output daily classification of whether one or more conditions of mental or emotional distress are identified or predicted. The ring application **345** may store application data **355**, such as acquired temperature data, other physiological data, pregnancy tracking data (e.g., event data), postpartum tracking data (e.g., event data), and mental or emotional distress tracking data.

[0111] In some cases, the system **300** may generate pregnancy, postpartum, and/or mental or emotional distress tracking data based on user physiological data (e.g., temperature data **320**). The pregnancy, postpartum, and/or mental or emotional distress tracking data may include a detected indication of the one or more conditions of mental or emotional distress for the user, that may be determined based on acquired user temperature data (e.g., daily temperature data **320**) over an analysis time period (e.g., a period of weeks/months). For example, the system **300** may receive physiological data associated with a user from a wearable device (e.g., ring **305**). The physiological data may include at least temperature data **320**, heart rate data **325**, respiratory rate data **330**, HRV data **335**, sleep data **340**, or a combination thereof. For example, the system **300** acquires user physiological data over an analysis time period (e.g., a plurality of days). In such cases, the system **300** may acquire and process user physiological data over an analysis time period to generate one or more time series of user physiological data.

[0112] In some cases, the system **300** may acquire daily user temperature data **320** over an analysis time period. For example, the system **300** may calculate a single temperature value for each day. The system **300** may acquire a plurality of temperature values during the day and/or night and process the acquired temperature values to determine the single daily temperature value. In some implementations, the system **300** may determine a time series of a plurality of temperature values taken over a plurality of days based on the received temperature data **320**. The system **300** may detect the indication of the one or more conditions of mental or emotional distress in the time series of the temperature values based on identifying that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user, as further shown and described with reference to FIG. **4**.

[0113] In some implementations, the system **300** may compute a delta in the time series of the plurality of temperature values. For example, the system **300** may identify that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values in response to computing the delta. The delta may be indicative of one or more conditions of mental or emotional distress. In such cases, the system **300** may detect an indication of one or more conditions of mental or emotional distress in response to computing the delta in the time series of the plurality of temperature values. The delta may be representative of a change in the progesterone levels of the user before birth and after birth regardless of the actual amount of progesterone before birth and after birth.

[0114] Biological and psychosocial factors may contribute to conditions of mental or emotional distress (e.g., including postpartum mood disorders). Biological factors may include circadian rhythm disturbance due to infant nighttime feeding and extensive hormonal shifts after giving birth. In some cases, shifts in estrogen, progesterone, prolactin, thyroid, cortisol, and hemoglobin may affect mood disorders. For example, a drop in progesterone may be one of the predictors of postpartum depression. In such cases, a drop in progesterone may be indicative of a drop in the temperature pattern of the user (e.g., the delta in the time series of the plurality of temperature values). For example, the user may experience a large decrease in progesterone after birth relative to a postpartum baseline of progesterone decrease, which may be a predictor for postpartum depression.

[0115] In some cases, the system **300** may determine that the received heart rate data (e.g., heart rate data **325**) deviates from a prenatal, perinatal, or postnatal baseline heart rate for the user for at least a portion of the plurality of days. In such cases, the system **300** may detect the indication of the one or more conditions of mental or emotional distress in response to determining that the received heart rate data deviates from the prenatal, perinatal, or postnatal baseline heart rate for the user. For example, the received heart rate data may exceed the prenatal, perinatal, or postnatal baseline heart rate for the user or is less than the prenatal, perinatal, or postnatal baseline heart rate for the user. The prenatal, perinatal, or postnatal baselines may refer to a baseline or average rates, or usual rate variations for the user as measured throughout pregnancy, postpartum period, or specific phases of pregnancy and/or postpartum period, that may differ from the user's normal or non-pregnant baselines.

[0116] In some cases, the system **300** may determine that the received respiratory rate data (e.g., respiratory rate data **330**) deviates from a prenatal, perinatal, or postnatal baseline respiratory rate for the user for at least a portion of the plurality of days. In such cases, the system **300** may detect the indication of the one or more conditions of mental or emotional distress in response to determining that the

received respiratory rate data deviates from the prenatal, perinatal, or postnatal baseline respiratory rate for the user. For example, the received respiratory rate data may exceed the prenatal, perinatal, or postnatal baseline respiratory rate for the user or is less than the prenatal, perinatal, or postnatal baseline respiratory rate for the user.

[0117] In some cases, the system **300** may determine that the received HRV data (e.g., HRV data **335**) deviates from a prenatal, perinatal, or postnatal baseline HRV for the user for at least a portion of the plurality of days. In such cases, the system **300** may detect the indication of the one or more conditions of mental or emotional distress in response to determining that the received HRV data is less than the prenatal, perinatal, or postnatal baseline HRV for the user. The HRV data **335** may include high frequency HRV data and low frequency HRV data. In such cases, the system **300** may determine that the low frequency HRV data deviates from a prenatal, perinatal, or postnatal baseline low frequency HRV for the user. The system **300** may detect the indication of the one or more conditions of mental or emotional distress in response to determining that the received low frequency HRV data deviates from the prenatal, perinatal, or postnatal baseline low frequency HRV for the user.

[0118] In some examples, users with postpartum anxiety or depressive symptoms may exhibit significantly lower HRV (e.g., high frequency, low frequency, and total power) than users without postpartum anxiety or depressive symptoms. Similarly, users that experience stress during pregnancy may exhibit significantly lower HRV (e.g., high frequency, low frequency, and total power) than users that do not experience stress during pregnancy. In some cases, users experiencing postpartum depression may also have symptoms of postpartum anxiety disorder that may be apparent in altered HRV values.

[0119] In some cases, the system **300** may measure a user's oxygen levels as well as sleep quality. The system **300** may inform the user of the levels and sleep quality, as a user may be unaware of the condition. In some implementations, the system **300** may display an alert to the user to pay attention to specific symptoms or consult a physician. By monitoring sleep measures, the system **300** may detect frequent awakenings, sleep length, sleep duration, proportion of sleep stages, and overall sleep efficiency. The system **300** may combine these measures with sleep data **340** and SpO2 data and recommend relevant tags (e.g., breathing difficulties, snoring, low energy, unrested) as well as calls for action (e.g., "Your oxygen levels are lower than usual, are you aware of snoring? If unsure, consult your physician."). The ability of a system **300** to continuously detect SpO2 data may be used to establish a typical oxygenation profile in healthy and high risk pregnancies. The system **300** may take into account the continuously detected SpO2 while also taking into account deviations from one's prior history as well as deviations from a typical pregnancy and/or postpartum profile and may alert users when tissue oxygenation falls below a threshold (e.g., Sleep data **340**<95%) and surface related tags (e.g., chest pain, dyspnea, etc.).

[0120] For example, the system **300** may determine that the received blood oxygen saturation data deviates from a prenatal, perinatal, or postnatal baseline blood oxygen saturation for the user for at least a portion of the plurality of days. In such cases, the system **300** may detect the indication of the one or more conditions of mental or emotional distress based on determining that the received blood oxygen saturation data is less than or greater than a prenatal, perinatal, or postnatal baseline blood oxygen saturation for the user.

[0121] In some implementations, the system **300** may determine that the received sleep data **340** deviates from a prenatal, perinatal, or postnatal baseline sleep data for the user for at least a portion of the plurality of days. In such cases, the system **300** may detect the indication of the one or more conditions of mental or emotional distress based on determining that the received sleep data **340** is less than or greater than a prenatal, perinatal, or postnatal baseline sleep data for the user. For example, the system **300** may determine that the quantity of detected sleep disturbances from the received sleep data **340** exceeds a prenatal, perinatal, or postnatal baseline sleep disturbance threshold for the user for at least a portion of the plurality of days. The system **300** may detect the indication of the one or more conditions of mental or emotional distress in response to determining that the quantity of detected sleep disturbances from the received sleep data **340** exceeds a prenatal, perinatal, or postnatal baseline sleep disturbance threshold for the user.

[0122] The detected sleep disturbances may be an example of postpartum sleep disturbances that may be a combination of sleep deprivation and sleep fragmentation. Disturbed sleep during pregnancy as well as in the postpartum period may increase the risk for postpartum depression. In some cases, symptoms of insomnia may be associated with significant risk for new-onset depression and anxiety disorders. For example, sleep characteristics associated with depression may include a short REM latency (e.g., the time it takes to enter REM sleep from sleep onset), difficulties initiating sleep, decreased sleep continuity (i.e., increased number of awakenings), decreased slow-wave sleep (i.e., decreased percentage of stage **3** or **4** sleep), and enhanced REM sleep.

[0123] In such cases, the sleep data **340** may include an amount of deep sleep, an amount of REM sleep, total sleep time, restfulness, sleep latency, sleep density, an amount of wake periods, or a combination thereof. The system **300** may determine that the amount of deep sleep, amount of REM sleep, total sleep time, restfulness, sleep latency, sleep density, amount of wake periods, or a combination thereof deviates from a prenatal, perinatal, or postnatal sleep baseline for the user for at least a portion of the plurality of days. In some examples, the system **300** may detect the indication of the one or more conditions of mental or emotional distress based on determining that the amount of deep sleep, amount of REM sleep, total sleep time, restfulness, sleep latency, sleep density, an amount of wake periods, or a combination thereof deviates from the prenatal, perinatal, or postnatal sleep baseline for the user.

[0124] The system **300** may determine that the physiological data deviates from the prenatal, perinatal, or postnatal baselines for the user by inputting the physiological data and the prenatal, perinatal, or postnatal baselines into a machine learning model and determining, based on inputting the physiological data and the baselines into the machine learning model, that the physiological data deviates from the baseline. In the example of temperature, the time series of the plurality of temperature values taken over the plurality of days may be overlayed with the prenatal, perinatal, or postnatal baseline of temperature values. The system **300** may determine whether the plurality of temperature values deviates from the prenatal, perinatal, or postnatal baseline of

temperature values based on overlaying (e.g., comparing) the plurality of temperature values with the baseline.

[0125] For example, the system **300** may determine a median temperature value of the user's temperature throughout the day and compare the median temperature value to the user's baseline median value. If the user's determined median temperature value is different (e.g., greater or less) than the user's baseline median temperature value by a threshold, the system **300** may identify the deviation. In other examples, the system **300** may calculate a slope of the determined time series (e.g., slope of a line indicating the user's changing temperature values over time) and compare the slope to a slope of the user's baseline time series of temperature values. The system **300** may determine that the slope of the determined time series is different than the slope of the user's baseline (e.g., the user's temperature is changing faster/slower compared to the user's normal temperature changes throughout the day). In such cases, the system **300** may identify that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user in response to calculating the slopes and determining the respective slopes are different.

[0126] In some cases, the system **300** may calculate one or more maximum temperature values, one or more minimum temperature values, or a combination thereof, of the time series of the plurality of temperature values. The system **300** may calculate one or more maximum temperature values, one or more minimum temperature values, or a combination thereof of the baseline time series of a plurality of temperature values. In such cases, the system **300** may compare the calculated maximum temperature values, minimum temperature values, and the like associated with the received temperature data (e.g., the time series of the plurality of temperature values) with the calculated maximum temperature values, minimum temperature values, and the like associated with the baseline temperature data (e.g., the baseline time series of the plurality of temperature values). In response to the comparison, the system **300** may determine that maximum temperature values, minimum temperature values, or both may exceed a threshold relative to the baseline temperature minimum and/or maximums, and identify the deviation.

[0127] In some aspects, deviations may include deviations between the user's maximum/minimum temperature values compared to the user's baseline data, a timing of the user's maximum/minimum temperature values relative to the user's baseline data, or both. For example, the system may identify that the user's maximum temperature value during a day occurred two hours later than normal, which may be indicative of a condition of mental or emotional distress. In such cases, the system may evaluate the relative timing of maximum/minimum temperature values relative to the user's circadian rhythm.

[0128] The system **300** may differentiate whether the deviations are due to a condition of mental or emotional distress experienced during a prenatal, perinatal, or postnatal period of pregnancy or other factors (e.g., illness, athletic training, travel, etc.). For example, the system **300** may receive a user input that the user is experiencing an illness unrelated to a period of pregnancy, and the system **300** may determine that the deviation are based on the illness rather than a condition of mental or emotional distress experienced during a prenatal, perinatal, or postnatal period of pregnancy. The system **300** may flag the physiological data received during the time period associated with the illness as outliers based on determining that the user is not experiencing a condition of mental or emotional distress associated with the pregnancy.

[0129] The prenatal, perinatal, or postnatal baselines (e.g., temperature, heart rate, respiratory rate, HRV, sleep disturbances, SpO2, and the like) may be tailored-specific to the user based on historical data **360** acquired by the system **300**. For example, these prenatal, perinatal, or postnatal baselines may represent baseline or average values of physiological parameters or typical trends of physiological values throughout a user's pregnancy and/or postpartum period, that may differ from the user's normal or non-pregnant baselines. In some cases, the prenatal, perinatal, or postnatal baselines may differ throughout the user's pregnancy and/or postpartum period (e.g., based on the different stages of pregnancy and postpartum) for each physiological parameter. In some cases, the prenatal, perinatal, or postnatal baselines may be based on known standards, averages among users, demographic-specific, and/or based on a user's prior pregnancies and postpartum periods.

[0130] The system **300** may calculate the prenatal, perinatal, or postnatal baselines (temperature, heart rate, respiratory rate, HRV, sleep disturbances, SpO2, and the like) based on inputting the received physiological data into a machine learning model. For example, the baselines may be calculated based on calculating an average temperature, heart rate, respiratory rate, HRV, SpO2 for a plurality of days (e.g., the past 30 days, 90 days, 40 weeks, etc.). In some cases, the baseline may be calculated based on calculating an average value for multiple time periods of the day. For example, the user's temperature may be calculated for each minute, hour, and the like of the calendar day. In some cases, the baselines may be calculated based on calculating a median value over the plurality of days. The machine learning model may classify the user's baseline according to average values or median values to determine the user's prenatal, perinatal, or postnatal baselines. In some examples, the system **300** may determine a time series of a baseline plurality of temperature values taken over the plurality of days.

[0131] In some cases, one or more physiological measurements may be combined to detect the indication of the one or more conditions of mental or emotional distress. In such cases, identifying the indication of the one or more conditions of mental or emotional distress may be based on one physiological measurement or a combination of physiological measurements (e.g., temperature data **320**, heart rate data **325**, respiratory rate data **330**, HRV data **335**, sleep data **340**). For example, the user's sleep data **340** in combination with the user's temperature data **320** may be an indicator that may characterize one or more conditions of mental or emotional distress.

[0132] In some cases, the physiological measurements may include activity data (e.g., movement). The activity data may be used to detect the one or more conditions of mental or emotional distress. In some examples, the activity data may be combined with a combination of physiological measurements (e.g., temperature data **320**, heart rate data **325**, respiratory rate data **330**, HRV data **335**, sleep data **340**) to identify the one or more conditions of mental or emotional distress. The system **300** may determine that the activity data deviates from the prenatal, perinatal, or postnatal baseline activity threshold for the user, and the system **300** may

detect the one or more conditions of mental or emotional based on the deviation. For example, the system **300** may determine that the user exercises less frequently during a prenatal, perinatal, or postnatal period (e.g., deviating from the prenatal, perinatal, or postnatal baseline activity threshold).

[0133] In some cases, the user's sleep data **340** may confirm (e.g., provide a definitive indication of or better prediction of) the indication of one or more one or more conditions of mental or emotional distress in light of the user's temperature data **320**. For example, if the system **300** determines that the quantity of detected sleep disturbances from the received sleep data **340** exceeds the prenatal, perinatal, or postnatal baseline sleep disturbance threshold for the user and that the received temperature data **320** deviates from the prenatal, perinatal, or postnatal baseline temperature for the user, the system **300** may validate or detect the indication of the one or more conditions of mental or emotional distress with greater accuracy and precision than if one of the sleep data **340** or temperature data **320** deviates from the prenatal, perinatal, or postnatal baseline.

[0134] In some examples, one or more physiological measurements may be combined to disprove or reduce the likelihood of a detected indication of one or more conditions of mental or emotional distress. In such cases, the system **300** may identify a false positive for identifying the indication of one or more conditions of mental or emotional distress based on one physiological measurement or a combination of physiological measurements. For example, if the system **300** determines that the received temperature data **320** deviates from the prenatal, perinatal, or postnatal baseline temperature for the user but the received sleep data **340** still aligns with the prenatal, perinatal, or postnatal baseline sleep data for the user, the system **300** may determine that the detected indication of one or more conditions of mental or emotional distress is invalid or at least less likely than if both the temperate and sleep data deviated from their prenatal, perinatal, or postnatal baselines. In such cases, the system **300** may determine that the user may be experiencing an illness, hormonal shift in the menstrual cycle, and the like.

[0135] In some cases, the user's logged symptoms (e.g., tags) in combination with the user's physiological data (e.g., temperature data **320**, heart rate data **325**, respiratory rate data **330**, HRV data **335**, sleep data **340**, or a combination thereof) may be an indicator that may characterize an indication of one or more conditions of mental or emotional distress. In such cases, the user's logged symptoms may confirm (e.g., provide a definitive indication of or better prediction of) the indication of one or more conditions of mental or emotional distress in light of the user's physiological data. For example, if the system **300** determines that the received temperature data **320** deviates from the prenatal, perinatal, or postnatal baseline temperature for the user and the system receives user input associated with the mental or emotional distress (e.g., stress, sadness, anxiousness, etc.), the system may validate or detect the indication of one or more conditions of mental or emotional distress with greater accuracy and precision than if one of the temperature data **320** deviates from the prenatal, perinatal, or postnatal baseline or the user logs mental or emotional distress symptoms.

[0136] In some cases, the user's interaction with the ring application **345** may be an indicator of one or more conditions of mental or emotional distress. For example, a frequency that the user accesses the ring application **345**, a duration of time that the user accesses the ring application **345**, a time of day that the user accesses the ring application **345**, or a combination thereof, may be an indicator of one or more conditions of mental or emotional distress. In some examples, the user's interaction with the ring application **345** in combination with the user's physiological data (e.g., temperature data **320**, heart rate data **325**, respiratory rate data **330**, HRV data **335**, sleep data **340**, or a combination thereof) may be an indicator of one or more conditions of mental or emotional distress.

[0137] In some examples, the system **300** may identify a false positive for identifying the indication of one or more conditions of mental or emotional distress based on the user input, one physiological measurement, a combination of physiological measurements, or a combination thereof. For example, if the system **300** determines that the received heart rate data **325** is greater than the prenatal, perinatal, or postnatal baseline heart rate for the user but the user input indicates a symptom associated with illness, a change in medication, and the like, the system **300** may determine that the detected indication of one or more conditions of mental or emotional distress is invalid (e.g., a false positive). In such cases, the system **300** may determine that the user may be experiencing an illness, hormonal shift in the menstrual cycle, and the like based on receiving the user input.

[0138] The system **300** may cause a GUI of the user devices **310**-*a*, **310**-*b* to display the indication of the one or more conditions of mental or emotional distress. In some cases, the system **300** may cause the GUI to display the time series. The system **300** may generate a tracking GUI that includes physiological data (e.g., at least temperature data **320**), tagged events, and/or other GUI elements described herein with reference to FIG. **4**. In such cases, the system **300** may render ovulations, periods, pregnancy, labor, birth, a pregnancy complication, and the like in a tracking GUI.

[0139] The system **300** may generate a message **370** for display on a GUI on a user device **310**-*a* or **310**-*b* that indicates the indication of the one or more conditions of mental or emotional distress. For example, the system **300** (e.g., user device **310**-*a* or server **315**) may transmit the message **370** that indicates the predicted and/or identified one or more conditions of mental or emotional distress to the user device **310**-*b*. In such cases, the user device **310**-*b* may be associated with a clinician, a fertility specialist, a caretaker, a partner, or a combination thereof. The detection of a probable condition of mental or emotional distress may trigger a personalized message **370** to a user highlighting the pattern detected in the temperature data and providing an educational link about conditions of mental or emotional distress during the prenatal, perinatal, or postnatal period of pregnancy.

[0140] In some implementations, the ring application **345** may notify the user of indication of one or more conditions of mental or emotional distress and/or prompt the user to perform a variety of tasks in the activity GUI. The notifications and prompts may include text, graphics, and/or other user interface elements. The notifications and prompts may be included in the ring application **345** such as when there are identified and/or predicted conditions of mental or emotional distress, the ring application **345** may display notifications and prompts. The user device **310** may display notifications and prompts in a separate window on the home

screen and/or overlaid onto other screens (e.g., at the very top of the home screen). In some cases, the user device **310** may display the notifications and prompts on a mobile device, a user's watch device, or both.

[0141] In some examples, the system **300** may provide mitigation advice. In such cases, the system **300** may provide recommendations on steps to take to confirm or disprove the indication of the conditions of mental or emotional distress. For example, if the system **300** determines that the user's heart rate is elevated above the prenatal, perinatal, or postnatal baseline heart rate, the system **300** may prompt the user to perform a meditation and/or breathing exercise a few times a day for a couple of days and the re-evaluate the heart rate data **325**. In such cases, the system **300** may receive the physiological data after the user performs the mitigation advice to determine whether the user is experiencing one or more conditions of mental or emotional distress, if the user is experiencing a period of illness, or both.

[0142] In some implementations, the user device **310** may store historical user data. In some cases, the historical user data may include historical data **360**. The historical data **360** may include historical temperature patterns of the user, historical heart rate patterns of the user, historical respiratory rate patterns of the user, historical HRV patterns of the user, historical sleep data, historical blood oxygen saturation of the user, historical pregnancy events (e.g., conception date, due date, delivery data, etc.) of the user, historical postpartum events, or a combination thereof. The historical data **360** may be selected from the last few months. The historical data **360** may be used (e.g., by the user device **310** or server **315**) to determine a threshold (e.g., prenatal, perinatal, or postnatal baseline) for the user, determine temperature values of the user, predict a condition of mental or emotional distress, identify a condition of mental or emotional distress, or a combination thereof. The historical data **360** may be used by the server **315**. Using the historical data **360** may allow the user device **310** and/or server **315** to personalize the GUI by taking into consideration the user's historical data **360**.

[0143] In such cases, the user device **310** may transmit historical data **360** to the server **315**. In some cases, the transmitted historical data **360** may be the same historical data stored in the ring application **345**. In other examples, the historical data **360** may be different than the historical data stored in the ring application **345**. The server **315** may receive the historical data **360**. The server **315** may store the historical data **360** in server data **365**.

[0144] In some implementations, the user device **310** and/or server **315** may also store other data that may be an example of user information. The user information may include, but is not limited to, user age, weight, height, body mass index, and gender, and medical history of the user. In some implementations, the user information may be used as features for predicting or identifying one or more conditions of mental or emotional distress. The server data **365** may include the other data such as user information.

[0145] In some implementations, the system **300** may include one or more user devices **310** for different users. For example, the system **300** may include user device **310**-*a* for a primary user and user device **310**-*b* for a second user **302** associated with the primary user (e.g., partner). The user devices **310** may measure physiological parameters of the different users, provide GUIs for the different users, and receive user input from the different users. In some implementations, the different user devices **310** may acquire physiological information and provide output related to a woman's health, such as menstrual cycles, ovarian cycles, illness, fertility, pregnancy, and/or postpartum. In some implementations, the user device **310**-*b* may acquire physiological information related to the second user **302**, such as male illness and fertility.

[0146] In some implementations, the system **300** may provide GUIs that inform the second user **302** of relevant information. For example, the first user and the second user **302** may share their information with one another via one or more user devices **310**, such as via a server device, mobile device, or other device. In some implementations, the second user **302** may share one or more of their accounts (e.g., usernames, login information, etc.) and/or associated data with one another (e.g., the first user). By sharing information between users, the system **300** may assist second users **302** in making health decisions related to pregnancy. In some implementations, the users may be prompted (e.g., in a GUI) to share specific information. For example, the user may use a GUI to opt into sharing her pregnancy and/or postpartum information with the second user **302**. In such cases, the user and the second user **302** may receive notifications on their respective user devices **310**. In other examples, a second user **302** may make their information (e.g., illness, pregnancy data, postpartum data, etc.) available to the user via a notification or other sharing arrangement. In such cases, the second user **302** may be an example of a clinician, a fertility specialist, a care-taker, a partner, or a combination thereof.

[0147] In some aspects, identified and/or predicted conditions of mental or emotional distress during a prenatal, perinatal, or postnatal period of pregnancy may be transmitted to a server or other platform that enables other users (e.g., clinicians, administrators, employers, trainers, etc.) to view the identified/predicted conditions. For example, the collected data, identified/predicted conditions, and/or generated insights may be transmitted to a multi-user platform or portal so that the user's clinician and other health professionals can make medical treatment decisions based on the identified or predicted conditions.

[0148] FIG. **4** illustrates an example of a GUI **400** that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure The GUI **400** may implement, or be implemented by, aspects of the system **100**, system **200**, system **300**, or any combination thereof. For example, the GUI **400** may be an example of a GUI **275** of a user device **106** (e.g., user device **106**-*a*, **106**-*b*, **106**-*c*) corresponding to a user **102**.

[0149] In some examples, the GUI **400** illustrates a series of application pages **405** that may be displayed to a user via the GUI **400** (e.g., GUI **275** illustrated in FIG. **2**). The server of the system may cause the GUI **400** of the user device (e.g., mobile device) to display inquiries of whether the user activates the pregnancy mode and wants to track their pregnancy (e.g., via application page **405**) or activates the postpartum mode and wants to the track their postpartum period (via application page **405**). In such cases, the system may generate a personalized tracking experience on the GUI **400** of the user device to predict a risk for conditions of mental or emotional distress during the prenatal, perinatal, or postnatal period or detect that the user is experiencing a

condition of mental or emotional distress based on the contextual tags and user questions.

[0150] Continuing with the examples above, prior to detecting the indication of the one or more conditions of mental or emotional distress of the user, the user may be presented with an application page upon opening the wearable application. The application page **405** may display a request to activate the pregnancy mode and enable the system to track the pregnancy or activate the postpartum mode and enable the system to track the postpartum period. In such cases, the application page **405** may display an invitation card where the users are invited to enroll in the pregnancy and/or postpartum tracking applications. The application page **405** may display a prompt to the user to verify whether the pregnancy and/or postpartum period may be tracked or dismiss the message if the pregnancy and/or postpartum period is not tracked. The system may receive an indication of whether the user selects to opt-in to tracking the pregnancy and/or postpartum period or opt-out to tracking the pregnancy and/or postpartum period.

[0151] The user may be presented with an application page **405** upon selecting "yes" to tracking the pregnancy and/or postpartum period. The application page **405** may display a prompt to the user to verify the main reason to track pregnancy and/or postpartum period. In such cases, the application page **405** may prompt the user to confirm the intent of tracking the pregnancy and/or postpartum period. For example, the system may receive, via the user device, a confirmation of the intended use of the pregnancy and/or postpartum tracking system.

[0152] In some cases, the user may be presented with an application page **405** upon confirming the intent. The application page **405** may display a prompt to the user to verify the day of conception, the due date, the delivery data, and the like. For example, the system may receive, via the user device, a confirmation of the birth (e.g., delivery date). In some cases, the application page **405** may display a prompt to the user to indicate whether the due date may not be determined.

[0153] In some cases, the user may be presented with an application page **405** upon confirming the due date and/or the indication of birth. The application page **405** may display a prompt to the user to verify whether the user experience any pregnancy-related complications, any pre-existing medical conditions, any fertility treatments used to achieve pregnancy, any sleep disturbances of the user (e.g., whether the user is a shift worker), and the like. For example, the system may receive, via the user device, a confirmation of whether the user experienced any pregnancy-related complications, any pre-existing medical conditions, any fertility treatments used to achieve pregnancy, any sleep disturbances of the user, and the like. Upon receiving the confirmations, the user may be presented with a GUI **400** that may be further shown and described with reference to application page **405**.

[0154] In some cases, the application page **405** may display a prompt to the user to input one or more tags associated with the pregnancy and/or postpartum period, one or more surveys, or both. For example, the user may be prompted to fill out a questionnaire (e.g., survey). The survey may include indications of whether the user feels like they have social support, the user's marital satisfaction, the user's perceived happiness, stress, and/or mood, a history of the user's substance abuse, partner violence, stress levels, life struggles, or a combination thereof. In some examples, the one or more tags may be an example of fatigue, baby care, emotions (e.g., sadness, anxiety, stress, etc.), and/or physiological measures like blood pressure.

[0155] Based on the input from the user, the system may alert a healthcare provider, provide the user with treatment suggestions and/or referrals to a healthcare provider, provide the user with tools to cope (e.g., take a quick walk, watch this video, complete this breathwork exercise, podcasts, other stores that users can relate to). In some cases, the system may provide stress management techniques (e.g., stress coaching) in response to detecting that the user is experiencing stress during pregnancy. For example, the system may receive user input including identified stressors in the user's life and provide suggestions on how to manage the stress. As users complete some of their suggested activities they may receive feedback from the system by seeing in real time how their actions mitigate their risk scores and/or change their scores, the content delivered, the messaging, or a combination thereof. In such cases, users may take control of their health by understanding what contributes and what does not contribute to mitigating their risk scores.

[0156] In some cases, the system may provide content to bring awareness to what conditions of mental or emotional distress are (i.e., including prenatal mood disorders and postpartum depression) such as what are the symptoms, what are the risks, and the importance of seeking help and/or treatment. In some cases, the system may deliver personalized messaging based on the birth outcome. For example, the system may message "Congratulations" based on receiving an indication of a positive birth outcome. In other examples, the system may provide suggestions of additional support resources based on receiving an indication of a negative birth outcome (e.g., loss of the baby, birth complications, baby transferred to the neonatal intensive care unit, etc.).

[0157] The server of the system may generate a message for display on the GUI **400** on a user device that indicates the indication of the one or more conditions of mental or emotional distress. For example, the server may cause the GUI **400** of the user device (e.g., mobile device) to display a message **420** associated with the indication of the one or more conditions of mental or emotional distress (e.g., via application page **405**). In such cases, the system may output the indication of the one or more conditions of mental or emotional distress on the GUI **400** of the user device to indicate that the user is experiencing a risk of one or more conditions of mental or emotional distress and/or one or more conditions of mental or emotional distress may be predicted for the future.

[0158] Continuing with the example above, upon detecting the indication of the one or more conditions of mental or emotional distress of the user, the user may be presented with the application page **405** upon opening the wearable application. As shown in FIG. **4**, the application page **405** may display the indication that the one or more conditions of mental or emotional distress is predicted and/or identified via message **420**. In such cases, the application page **405** may include the message **420** on the home page. In cases where a user's conditions of mental or emotional distress are predicted and/or identified, as described herein, the server may transmit a message **420** to the user, where the message **420** is associated with the predicted and/or identified one or more conditions of mental or emotional distress. In some

cases, the server may transmit a message **420** to a clinician, a fertility specialist, a care-taker, a partner of the user, or a combination thereof. In such cases, the system may present application page **405** on the user device associated with the clinician, the fertility specialists, the care-taker, the partner, or a combination thereof.

[0159] For example, the user may receive message **420**, that may indicate a time interval that the condition of mental or emotional distress occurred, a time interval during that condition of mental or emotional distress is predicted to occur, a request to input symptoms associated with the condition of mental or emotional distress, educational content associated with the condition of mental or emotional distress, an adjusted set of sleep targets, an adjusted set of activity targets, recommendations to improve symptoms associated with the condition of mental or emotional distress, a recommendation to consult a clinician, and the like. For example, the message **420** may indicate a risk associated with the condition of mental or emotional distress. The messages **420** may be configurable/customizable, such that the user may receive different messages **420** based on the predication and identification of the one or more conditions of mental or emotional distress, as described previously herein.

[0160] As shown in FIG. **4**, the application page **405** may display the indication of the one or more conditions of mental or emotional distress via alert **410**. The user may receive alert **410**, that may prompt the user to verify whether the one or more conditions of mental or emotional distress have occurred or dismiss the alert **410** if the one or more conditions of mental or emotional distress have not occurred. In such cases, the application page **405** may prompt the user to confirm or dismiss the one or more conditions of mental or emotional distress (e.g., confirm/deny whether the system correctly detected the indication of the one or more conditions of mental or emotional distress and/or confirm/deny whether the one or more conditions of mental or emotional distress have been confirmed via a clinician). For example, the system may receive, via the user device and in response to detecting the indication of the one or more conditions of mental or emotional distress, a confirmation of the one or more conditions of mental or emotional distress.

[0161] In some cases, the system may receive a confirmation of the one or more conditions of mental or emotional distress, one or more pregnancy symptoms, one or more postpartum symptoms, or a combination thereof. For example, the clinician, fertility specialist, or user may input the confirmation of the one or more pregnancy complications. In such cases, the system may detect the indication of the one or more conditions of mental or emotional distress in response to receiving the confirmation.

[0162] Additionally, in some implementations, the application page **405** may display one or more scores (e.g., Sleep Score, Readiness Score, Activity Score, etc.) for the user for the respective day. Moreover, in some cases, the predicted and/or identified one or more conditions of mental or emotional distress may be used to update (e.g., modify) one or more scores associated with the user (e.g., Sleep Score, Readiness Score, etc.). That is, data associated with the predicted and/or identified one or more conditions of mental or emotional distress may be used to update the scores for the user for the following calendar days. In such cases, the system may notify the user of the score update via alert **410**.

[0163] In some cases, the Readiness Score may be updated based on the detected indication of the one or more conditions of mental or emotional distress. In such cases, the Readiness Score may indicate to the user to "pay attention" based on the predicted and/or identified one or more conditions of mental or emotional distress. If the Readiness Score changes for the user, the system may implement a recovery mode for users whose symptoms may be severe and may benefit from adjusted activity and Readiness guidance for a couple of days. In other examples, the Readiness Score may be updated based on the Sleep Score. However, the system may determine that the user is experiencing one or more conditions of mental or emotional distress or predicted to experience one or more conditions of mental or emotional distress and may adjust the Readiness Score, Sleep Score, and/or Activity Score to offset the effects of the one or more conditions of mental or emotional distress.

[0164] In some cases, the messages **420** displayed to the user via the GUI **400** of the user device may indicate how the predicted and/or identified one or more conditions of mental or emotional distress affected the overall scores (e.g., overall Readiness Score) and/or the individual contributing factors. For example, a message may indicate "It looks like your body is under strain right now, but if you're feeling ok, doing a light or medium intensity exercise can help your body battle the symptoms" or "From your recovery metrics it looks like your body is still doing ok, so some light activity can help relieve the symptoms. Hope you'll feel better tomorrow!" In cases where the one or more conditions of mental or emotional distress are predicted and/or identified, the messages **420** may provide suggestions for the user in order to improve their general health. For example, the message may indicate "If you feel really low on energy, why not switch to rest mode for today," or "Since you may be experiencing stress during pregnancy, devote today for rest and relaxation." In such cases, the messages **420** displayed to the user may provide targeted insights to help the user adjust their lifestyle.

[0165] In some implementations, the system may notify, via alert **410** or message **420**, a user during pregnancy if their measures are abnormal. For example, the system may detect an increase in sleep disturbances and recommend related tags. In some implementations, the system may combine information from tags and user data. In response to detection of abnormal measures and/or user tags, a device may alert users when they may want to rest, pay close attention to specific symptoms, or consult their physician. The combination of multiple, continuous, high quality signals with tagged symptoms in the application may provide the basis for an interactive algorithm that takes into account deviations from one's prior history as well as deviations from a typical prenatal, perinatal, or postnatal profile. Tags surfaced to the user through the application may bring awareness to specific symptoms that the user might otherwise mistake for typical pregnancy and/or postpartum symptoms (e.g., tiredness, fatigue, etc.). Additional notifications may point to signals that require further attention, such as "You have been experiencing periods of sadness for a while now following the birth of your child, have you discussed this with your physician?", or "Your low frequency HRV appears to be high, you may want to take it easy this week and incorporate rest times in your schedule."

[0166] The application page **405** may indicate one or more parameters, including a temperature, heart rate, HRV, respi-

ratory rate, sleep data, and the like experienced by the user during the one or more conditions of mental or emotional distress via the graphical representation **415**. In such cases, the system may cause the GUI **400** of a user device to display a message **420**, alert **410**, or graphical representation **415** associated with the detected indication of one or more conditions of mental or emotional distress.

[0167] For example, the system may provide, via graphical representation **415**, the user with a trend graph for the user's physiologic and/or symptom data against a comparison graph of the range considered "normal," so that the user can understand their body and make informed choices about seeking medical care. In another example, the system may alert users when they should consider discussing their symptoms with a physician. In some implementations, the system may output a predicted risk score for conditions of mental or emotional distress. In some implementations, users with prior pregnancies and/or postpartum periods where they experienced conditions of mental or emotional distress may be able to activate/label a "history of mental or emotional distress" mode/tag to activate a more sensitive/conservative alert criteria.

[0168] In some cases, the user may log symptoms via user input **425**. For example, the system may receive user input (e.g., tags) to log symptoms associated with the one or more conditions of mental or emotional distress (e.g., difficulty sleeping, sadness, anxiety, etc.), pregnancy symptom tags, postpartum symptom tags, stress symptom tags, or the like. The system may recommend tags to the user based on user history and the predicted and/or identified one or more conditions of mental or emotional distress. In some cases, the system may cause the GUI **400** of the user device to display symptom tags based on a correlation between prior user symptom tags and a timing of the one or more conditions of mental or emotional distress.

[0169] Application page **405** may also include message **420** that includes insights, recommendations, and the like associated with the predicted and/or identified one or more conditions of mental or emotional distress. The server of the system may cause the GUI **400** of the user device to display a message **420** associated with the predicted and/or identified one or more conditions of mental or emotional distress. The user device may display recommendations and/or information associated with the predicted and/or identified one or more conditions of mental or emotional distress via message **420**. As noted previously herein, an accurately predicted and/or identified one or more conditions of mental or emotional distress may be beneficial to a user's overall health and recovery process.

[0170] In some implementations, the system may provide additional insight regarding the user's predicted and/or identified one or more conditions of mental or emotional distress. For example, the application pages **405** may indicate one or more physiological parameters (e.g., contributing factors) that resulted in the user's predicted and/or identified one or more conditions of mental or emotional distress, such as deviations of temperature relative to a prenatal, perinatal, or postnatal baseline, and the like. In other words, the system may be configured to provide some information or other insights regarding the predicted and/or identified one or more conditions of mental or emotional distress. Personalized insights may indicate aspects of collected physiological data (e.g., contributing factors within the physiological data) that were used to generate the predicted and/or identified one or more conditions of mental or emotional distress.

[0171] In some implementations, the system may be configured to receive user inputs regarding the identified and/or predicted one or more conditions of mental or emotional distress in order to train classifiers (e.g., supervised learning for a machine learning classifier) and improve conditions of mental or emotional distress determination and/or prediction techniques. For example, the user device may receive user inputs **425**, and these user inputs **425** may then be input into the classifier to train the classifier. For example, the system may employ a trained a model (e.g., a classifier) to take the last month(s) of a user's data and make a prediction about the probability that a user will exhibit conditions of mental or emotional distress at a given point in time, relative to the start of the pregnancy and/or postpartum period. In some implementations, different deep learning representations (e.g., gated recurrent units (GRUs), convolution neural networks (CNNs), LSTMS, Inception Time neural networks, etc.) may be used to derive embeddings that better represent the physiology data for prediction.

[0172] Upon predicting and/or identifying the one or more conditions of mental or emotional distress on application page **405**, the GUI **400** may display a calendar view that may indicate a current date that the user is viewing application page **405**, a date range including the day when the one or more conditions of mental or emotional distress are predicted and/or identified, and a date range including the day when the one or more conditions of mental or emotional distress are predicted and/or identified. For example, the date range may encircle the calendar days using a dashed line configuration, the current date may encircle the calendar day, and the day when one or more conditions of mental or emotional distress are predicted may be encircled. The calendar view may also include a message including the current calendar day and indication of the day of the user's pregnancy (e.g., that the user is 32 weeks pregnant).

[0173] FIG. **5** shows a block diagram **500** of a device **505** that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure. The device **505** may include an input module **510**, an output module **515**, and a wearable application **520**. The device **505** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

[0174] The input module **510** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to illness detection techniques). Information may be passed on to other components of the device **505**. The input module **510** may utilize a single antenna or a set of multiple antennas.

[0175] The output module **515** may provide a means for transmitting signals generated by other components of the device **505**. For example, the output module **515** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to illness detection techniques). In some examples, the output module **515** may

be co-located with the input module **510** in a transceiver module. The output module **515** may utilize a single antenna or a set of multiple antennas.

[0176] For example, the wearable application **520** may include a data acquisition component **525**, a temperature data component **530**, a deviation component **535**, a condition component **540**, a user interface component **545**, or any combination thereof. In some examples, the wearable application **520**, or various components thereof, may be configured to perform various operations (e.g., receiving, monitoring, transmitting) using or otherwise in cooperation with the input module **510**, the output module **515**, or both. For example, the wearable application **520** may receive information from the input module **510**, send information to the output module **515**, or be integrated in combination with the input module **510**, the output module **515**, or both to receive information, transmit information, or perform various other operations as described herein.

[0177] The data acquisition component **525** may be configured as or otherwise support a means for receiving, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data. The temperature data component **530** may be configured as or otherwise support a means for determining a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data. The deviation component **535** may be configured as or otherwise support a means for identifying that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series. The condition component **540** may be configured as or otherwise support a means for detecting an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user. The user interface component **545** may be configured as or otherwise support a means for generating a message for display on a GUI on a user device that indicates the indication of the condition of mental or emotional distress.

[0178] FIG. **6** shows a block diagram **600** of a wearable application **620** that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure. The wearable application **620** may be an example of aspects of a wearable application or a wearable application **520**, or both, as described herein. The wearable application **620**, or various components thereof, may be an example of means for performing various aspects of prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data as described herein. For example, the wearable application **620** may include a data acquisition component **625**, a temperature data component **630**, a deviation component **635**, a condition component **640**, a user interface component **645**, or any combination thereof. Each of these components may communicate, directly or indirectly, with one another (e.g., via one or more buses).

[0179] The data acquisition component **625** may be configured as or otherwise support a means for receiving, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data. The temperature data component **630** may be configured as or otherwise support a means for determining a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data. The deviation component **635** may be configured as or otherwise support a means for identifying that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series. The condition component **640** may be configured as or otherwise support a means for detecting an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user. The user interface component **645** may be configured as or otherwise support a means for generating a message for display on a GUI on a user device that indicates the indication of the condition of mental or emotional distress.

[0180] In some examples, the temperature data component **630** may be configured as or otherwise support a means for computing a delta in the time series of the plurality of temperature values based at least in part on determining the time series, wherein identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values is based at least in part on computing the delta.

[0181] In some examples, the physiological data further comprises sleep data, and the data acquisition component **625** may be configured as or otherwise support a means for determining that a quantity of detected sleep disturbances from the received sleep data exceeds a prenatal, perinatal, or postnatal baseline sleep disturbance threshold for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the quantity of detected sleep disturbances exceeds the prenatal, perinatal, or postnatal baseline sleep disturbance threshold for the user.

[0182] In some examples, the data acquisition component **625** may be configured as or otherwise support a means for determining that the sleep data deviates from a prenatal, perinatal, or postnatal baseline sleep threshold for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the sleep data deviates from the prenatal, perinatal, or postnatal baseline sleep threshold for the user.

[0183] In some examples, the physiological data further comprises HRV data, and the data acquisition component **625** may be configured as or otherwise support a means for determining that the received HRV data is less than a prenatal, perinatal, or postnatal baseline HRV for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the received HRV data is less than the prenatal, perinatal, or postnatal baseline HRV for the user.

[0184] In some examples, the physiological data further comprises low frequency HRV data, and the data acquisition component **625** may be configured as or otherwise support a means for determining that the received low frequency HRV data deviates from a prenatal, perinatal, or postnatal

baseline low frequency HRV for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the received low frequency HRV data deviates from the prenatal, perinatal, or postnatal baseline low frequency HRV for the user.

[0185] In some examples, the physiological data further comprises heart rate data, and the data acquisition component **625** may be configured as or otherwise support a means for determining that the received heart rate data deviates from a prenatal, perinatal, or postnatal baseline heart rate for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the received heart rate data deviates from the prenatal, perinatal, or postnatal baseline heart rate for the user.

[0186] In some examples, the physiological data further comprises respiratory rate data, and the data acquisition component **625** may be configured as or otherwise support a means for determining that the received respiratory rate data deviates from a prenatal, perinatal, or postnatal baseline respiratory rate for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the received respiratory rate data deviates from the prenatal, perinatal, or postnatal baseline respiratory rate for the user.

[0187] In some examples, the physiological data further comprises blood oxygen saturation data, and the data acquisition component **625** may be configured as or otherwise support a means for determining that the received blood oxygen saturation data deviates from a prenatal, perinatal, or postnatal baseline blood oxygen saturation for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the received blood oxygen saturation data deviates from the prenatal, perinatal, or postnatal baseline blood oxygen saturation for the user.

[0188] In some examples, the user interface component **645** may be configured as or otherwise support a means for receiving, via the GUI, a user input comprising a confirmation of the condition of mental or emotional distress, one or more pregnancy symptoms, one or more postpartum symptoms, or a combination thereof, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on receiving the user input.

[0189] In some examples, the user interface component **645** may be configured as or otherwise support a means for receiving, via the GUI, a user input indicating an age of the user, a body mass index of the user, a medical history of the user, an indication of birth, an indication of a pregnancy mode, an indication of a postpartum mode, one or more tags, one or more surveys, or a combination thereof, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on receiving the user input.

[0190] In some examples, the condition component **640** may be configured as or otherwise support a means for estimating a likelihood of a future condition of mental or emotional distress during the prenatal, perinatal, or postnatal period of pregnancy based at least in part on identifying that the plurality of temperature values deviates from than the prenatal, perinatal, or postnatal baseline of temperature values.

[0191] In some examples, the condition component **640** may be configured as or otherwise support a means for updating a Readiness Score associated with the user, an Activity Score associated with the user, a Sleep Score associated with the user, or a combination thereof, based at least in part on detecting the indication of the condition of mental or emotional distress.

[0192] In some examples, the user interface component **645** may be configured as or otherwise support a means for transmitting the message that indicates the indication of the condition of mental or emotional distress to the user device, wherein the user device is associated with a clinician, the user, or both.

[0193] In some examples, the user interface component **645** may be configured as or otherwise support a means for causing the GUI of the user device to display pregnancy symptom tags, postpartum symptom tags, stress symptom tags, or any combination thereof, based at least in part on detecting the indication of the condition of mental or emotional distress.

[0194] In some examples, the user interface component **645** may be configured as or otherwise support a means for causing the GUI of the user device to display the message associated with the indication of the condition of mental or emotional distress.

[0195] In some examples, the message further comprises a time interval that the condition of mental or emotional distress occurred, a time interval that the condition of mental or emotional distress is predicted to occur, a request to input symptoms associated with the condition of mental or emotional distress, educational content associated with the condition of mental or emotional distress, an adjusted set of sleep targets, an adjusted set of activity targets, recommendations to improve symptoms associated with the condition of mental or emotional distress, a recommendation to consult a clinician, a risk score associated with the condition of mental or emotional distress, or a combination thereof.

[0196] In some examples, the condition component **640** may be configured as or otherwise support a means for inputting the physiological data into a machine learning classifier, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on inputting the physiological data into the machine learning classifier.

[0197] In some examples, the condition of mental or emotional distress comprises stress during pregnancy, stress during postpartum, postpartum anxiety, postpartum obsessive-compulsive disorder, postpartum panic disorder, postpartum post-traumatic stress disorder, postpartum psychosis, postpartum depression, or any combination thereof.

[0198] In some examples, the wearable device comprises a wearable ring device.

[0199] In some examples, the wearable device collects the physiological data from the user based on arterial blood flow, capillary blood flow, arteriole blood flow, or a combination thereof.

[0200] FIG. **7** shows a diagram of a system **700** including a device **705** that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure. The device **705** may be an example of or include the components of a device **505** as described herein. The device **705** may include an example of a user device **106**, as described previously herein. The

device **705** may include components for bi-directional communications including components for transmitting and receiving communications with a wearable device **104** and a server **110**, such as a wearable application **720**, a communication module **710**, an antenna **715**, a user interface component **725**, a database (application data) **730**, a memory **735**, and a processor **740**. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more buses (e.g., a bus **745**).

[0201] The communication module **710** may manage input and output signals for the device **705** via the antenna **715**. The communication module **710** may include an example of the communication module **220**-*b* of the user device **106** shown and described in FIG. **2**. In this regard, the communication module **710** may manage communications with the ring **104** and the server **110**, as illustrated in FIG. **2**. The communication module **710** may also manage peripherals not integrated into the device **705**. In some cases, the communication module **710** may represent a physical connection or port to an external peripheral. In some cases, the communication module **710** may utilize an operating system such as iOS®, ANDROID®, MS-DOS®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In other cases, the communication module **710** may represent or interact with a wearable device (e.g., ring **104**), modem, a keyboard, a mouse, a touchscreen, or a similar device. In some cases, the communication module **710** may be implemented as part of the processor **740**. In some examples, a user may interact with the device **705** via the communication module **710**, user interface component **725**, or via hardware components controlled by the communication module **710**.

[0202] In some cases, the device **705** may include a single antenna **715**. However, in some other cases, the device **705** may have more than one antenna **715**, that may be capable of concurrently transmitting or receiving multiple wireless transmissions. The communication module **710** may communicate bi-directionally, via the one or more antennas **715**, wired, or wireless links as described herein. For example, the communication module **710** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The communication module **710** may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas **715** for transmission, and to demodulate packets received from the one or more antennas **715**.

[0203] The user interface component **725** may manage data storage and processing in a database **730**. In some cases, a user may interact with the user interface component **725**. In other cases, the user interface component **725** may operate automatically without user interaction. The database **730** may be an example of a single database, a distributed database, multiple distributed databases, a data store, a data lake, or an emergency backup database.

[0204] The memory **735** may include RAM and ROM. The memory **735** may store computer-readable, computer-executable software including instructions that, when executed, cause the processor **740** to perform various functions described herein. In some cases, the memory **735** may contain, among other things, a BIOS that may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0205] The processor **740** may include an intelligent hardware device, (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some cases, the processor **740** may be configured to operate a memory array using a memory controller. In other cases, a memory controller may be integrated into the processor **740**. The processor **740** may be configured to execute computer-readable instructions stored in a memory **735** to perform various functions (e.g., functions or tasks supporting a method and system for sleep staging algorithms).

[0206] For example, the wearable application **720** may be configured as or otherwise support a means for receiving, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data. The wearable application **720** may be configured as or otherwise support a means for determining a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data. The wearable application **720** may be configured as or otherwise support a means for identifying that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series. The wearable application **720** may be configured as or otherwise support a means for detecting an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user. The wearable application **720** may be configured as or otherwise support a means for generating a message for display on a GUI on a user device that indicates the indication of the condition of mental or emotional distress.

[0207] By including or configuring the wearable application **720** in accordance with examples as described herein, the device **705** may support techniques for improved communication reliability, reduced latency, improved user experience related to reduced processing, reduced power consumption, more efficient utilization of communication resources, improved coordination between devices, longer battery life, improved utilization of processing capability.

[0208] The wearable application **720** may include an application (e.g., "app"), program, software, or other component that is configured to facilitate communications with a ring **104**, server **110**, other user devices **106**, and the like. For example, the wearable application **720** may include an application executable on a user device **106** that is configured to receive data (e.g., physiological data) from a ring **104**, perform processing operations on the received data, transmit and receive data with the servers **110**, and cause presentation of data to a user **102**.

[0209] FIG. **8** shows a flowchart illustrating a method **800** that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure. The operations of the method **800** may be implemented by a user device or its components as described herein. For example, the operations of the method **800** may be performed by a user device as described with reference to FIGS. **1** through **7**. In some examples, a user

device may execute a set of instructions to control the functional elements of the user device to perform the described functions. Additionally, or alternatively, the user device may perform aspects of the described functions using special-purpose hardware.

[0210] At **805**, the method may include receiving, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data. The operations of **805** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **805** may be performed by a data acquisition component **625** as described with reference to FIG. **6**.

[0211] At **810**, the method may include determining a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data. The operations of **810** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **810** may be performed by a temperature data component **630** as described with reference to FIG. **6**.

[0212] At **815**, the method may include identifying that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series. The operations of **815** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **815** may be performed by a deviation component **635** as described with reference to FIG. **6**.

[0213] At **820**, the method may include detecting an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user. The operations of **820** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **820** may be performed by a condition component **640** as described with reference to FIG. **6**.

[0214] At **825**, the method may include generating a message for display on a GUI on a user device that indicates the indication of the condition of mental or emotional distress. The operations of **825** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **825** may be performed by a user interface component **645** as described with reference to FIG. **6**.

[0215] FIG. **9** shows a flowchart illustrating a method **900** that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure. The operations of the method **900** may be implemented by a user device or its components as described herein. For example, the operations of the method **900** may be performed by a user device as described with reference to FIGS. **1** through **7**. In some examples, a user device may execute a set of instructions to control the functional elements of the user device to perform the described functions. Additionally, or alternatively, the user device may perform aspects of the described functions using special-purpose hardware.

[0216] At **905**, the method may include receiving, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data. The operations of **905** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **905** may be performed by a data acquisition component **625** as described with reference to FIG. **6**.

[0217] At **910**, the method may include determining a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data. The operations of **910** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **910** may be performed by a temperature data component **630** as described with reference to FIG. **6**.

[0218] At **915**, the method may include computing a delta in the time series of the plurality of temperature values based at least in part on determining the time series. The operations of **915** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **915** may be performed by a temperature data component **630** as described with reference to FIG. **6**.

[0219] At **920**, the method may include identifying that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series, wherein identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values is based at least in part on computing the delta. The operations of **920** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **920** may be performed by a deviation component **635** as described with reference to FIG. **6**.

[0220] At **925**, the method may include detecting an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user. The operations of **925** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **925** may be performed by a condition component **640** as described with reference to FIG. **6**.

[0221] At **930**, the method may include generating a message for display on a GUI on a user device that indicates the indication of the condition of mental or emotional distress. The operations of **930** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **930** may be performed by a user interface component **645** as described with reference to FIG. **6**.

[0222] FIG. **10** shows a flowchart illustrating a method **1000** that supports prenatal, perinatal, or postnatal mental or emotional distress identification and prediction from wearable-based physiological data in accordance with aspects of the present disclosure. The operations of the method **1000** may be implemented by a user device or its components as described herein. For example, the operations of the method **1000** may be performed by a user device as described with reference to FIGS. **1** through **7**. In some examples, a user device may execute a set of instructions to control the functional elements of the user device to perform the described functions. Additionally, or alternatively, the user device may perform aspects of the described functions using special-purpose hardware.

[0223] At **1005**, the method may include receiving, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data. The operations of **1005** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1005** may be performed by a data acquisition component **625** as described with reference to FIG. **6**.

[0224] At **1010**, the method may include determining a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data. The operations of **1010** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1010** may be performed by a temperature data component **630** as described with reference to FIG. **6**.

[0225] At **1015**, the method may include identifying that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series. The operations of **1015** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1015** may be performed by a deviation component **635** as described with reference to FIG. **6**.

[0226] At **1020**, the method may include receiving, via the GUI, a user input indicating an age of the user, a body mass index of the user, a medical history of the user, an indication of birth, an indication of a pregnancy mode, an indication of a postpartum mode, one or more tags, one or more surveys, or a combination thereof. The operations of **1020** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1020** may be performed by a user interface component **645** as described with reference to FIG. **6**.

[0227] At **1025**, the method may include detecting an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on receiving the user input. The operations of **1025** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1025** may be performed by a condition component **640** as described with reference to FIG. **6**.

[0228] At **1030**, the method may include generating a message for display on a GUI on a user device that indicates the indication of the condition of mental or emotional distress. The operations of **1030** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1030** may be performed by a user interface component **645** as described with reference to FIG. **6**.

[0229] It should be noted that the methods described above describe possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Furthermore, aspects from two or more of the methods may be combined.

[0230] A method is described. The method may include receiving, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data, determining a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data, identifying that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series, detecting an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user, and generating a message for display on a GUI on a user device that indicates the indication of the condition of mental or emotional distress.

[0231] An apparatus is described. The apparatus may include a processor, memory coupled with the processor, and instructions stored in the memory. The instructions may be executable by the processor to cause the apparatus to receive, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data, determine a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data, identify that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series, detect an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user, and generate a message for display on a GUI on a user device that indicates the indication of the condition of mental or emotional distress.

[0232] Another apparatus is described. The apparatus may include means for receiving, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data, means for determining a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data, means for identifying that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series, means for detecting an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user, and means for generating a message for display on a GUI on a user device that indicates the indication of the condition of mental or emotional distress.

[0233] A non-transitory computer-readable medium storing code is described. The code may include instructions executable by a processor to receive, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data, determine a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data, identify that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the

user based at least in part on determining the time series, detect an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user, and generate a message for display on a GUI on a user device that indicates the indication of the condition of mental or emotional distress.

[0234] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for computing a delta in the time series of the plurality of temperature values based at least in part on determining the time series, wherein identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values may be based at least in part on computing the delta.

[0235] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the physiological data further comprises sleep data and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for determining that a quantity of detected sleep disturbances from the received sleep data exceeds a prenatal, perinatal, or postnatal baseline sleep disturbance threshold for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress may be based at least in part on determining that the quantity of detected sleep disturbances exceeds the prenatal, perinatal, or postnatal baseline sleep disturbance threshold for the user.

[0236] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for determining that the sleep data deviates from a prenatal, perinatal, or postnatal baseline sleep threshold for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress may be based at least in part on determining that the sleep data deviates from the prenatal, perinatal, or postnatal baseline sleep threshold for the user.

[0237] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the physiological data further comprises HRV data and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for determining that the received HRV data may be less than a prenatal, perinatal, or postnatal baseline HRV for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress may be based at least in part on determining that the received HRV data may be less than the prenatal, perinatal, or postnatal baseline HRV for the user.

[0238] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the physiological data further comprises low frequency HRV data and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for determining that the received low frequency HRV data deviates from a prenatal, perinatal, or postnatal baseline low frequency HRV for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress may be based at least in part on determining that the received low frequency HRV data deviates from the prenatal, perinatal, or postnatal baseline low frequency HRV for the user.

[0239] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the physiological data further comprises heart rate data and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for determining that the received heart rate data deviates from a prenatal, perinatal, or postnatal baseline heart rate for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress may be based at least in part on determining that the received heart rate data deviates from the prenatal, perinatal, or postnatal baseline heart rate for the user.

[0240] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the physiological data further comprises respiratory rate data and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for determining that the received respiratory rate data deviates from a prenatal, perinatal, or postnatal baseline respiratory rate for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress may be based at least in part on determining that the received respiratory rate data deviates from the prenatal, perinatal, or postnatal baseline respiratory rate for the user.

[0241] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the physiological data further comprises blood oxygen saturation data and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for determining that the received blood oxygen saturation data deviates from a prenatal, perinatal, or postnatal baseline blood oxygen saturation for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress may be based at least in part on determining that the received blood oxygen saturation data deviates from the prenatal, perinatal, or postnatal baseline blood oxygen saturation for the user.

[0242] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving, via the GUI, a user input comprising a confirmation of the condition of mental or emotional distress, one or more pregnancy symptoms, one or more postpartum symptoms, or a combination thereof, wherein detecting the indication of the condition of mental or emotional distress may be based at least in part on receiving the user input.

[0243] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving, via the GUI, a user input indicating an age of the user, a body mass index of the user, a medical history of the user, an indication of birth, an indication of a pregnancy mode, an indication of a postpartum mode, one or more tags, one or more surveys, or a combination thereof, wherein detecting the indication of the condition of mental or emotional distress may be based at least in part on receiving the user input.

[0244] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for estimating a likelihood of a future condition of mental or emotional distress during the prenatal, perinatal, or postnatal period of pregnancy based at least in part on identifying that the plurality of temperature values deviates from than the prenatal, perinatal, or postnatal baseline of temperature values.

[0245] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for updating a Readiness Score associated with the user, an Activity Score associated with the user, a Sleep Score associated with the user, or a combination thereof, based at least in part on detecting the indication of the condition of mental or emotional distress.

[0246] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for transmitting the message that indicates the indication of the condition of mental or emotional distress to the user device, wherein the user device may be associated with a clinician, the user, or both.

[0247] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for causing the GUI of the user device to display pregnancy symptom tags, postpartum symptom tags, stress symptom tags, or any combination thereof, based at least in part on detecting the indication of the condition of mental or emotional distress.

[0248] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for causing the GUI of the user device to display the message associated with the indication of the condition of mental or emotional distress.

[0249] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the message further comprises a time interval that the condition of mental or emotional distress occurred, a time interval that the condition of mental or emotional distress may be predicted to occur, a request to input symptoms associated with the condition of mental or emotional distress, educational content associated with the condition of mental or emotional distress, an adjusted set of sleep targets, an adjusted set of activity targets, recommendations to improve symptoms associated with the condition of mental or emotional distress, a recommendation to consult a clinician, a risk score associated with the condition of mental or emotional distress, or a combination thereof.

[0250] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for inputting the physiological data into a machine learning classifier, wherein detecting the indication of the condition of mental or emotional distress may be based at least in part on inputting the physiological data into the machine learning classifier.

[0251] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the condition of mental or emotional distress comprises stress during pregnancy, stress during postpartum, postpartum anxiety, postpartum obsessive-compulsive disorder, postpartum panic disorder, postpartum post-traumatic stress disorder, postpartum psychosis, postpartum depression, or any combination thereof.

[0252] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the wearable device comprises a wearable ring device.

[0253] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the wearable device collects the physiological data from the user based on arterial blood flow, capillary blood flow, arteriole blood flow, or a combination thereof.

[0254] The description set forth herein, in connection with the appended drawings, describes example configurations and does not represent all the examples that may be implemented or that are within the scope of the claims. The term "exemplary" used herein means "serving as an example, instance, or illustration," and not "preferred" or "advantageous over other examples." The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances, well-known structures and devices are shown in block diagram form in order to avoid obscuring the concepts of the described examples.

[0255] In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If just the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

[0256] Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0257] The various illustrative blocks and modules described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration).

[0258] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software,

functions described above can be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations. Also, as used herein, including in the claims, "or" as used in a list of items (for example, a list of items prefaced by a phrase such as "at least one of" or "one or more of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an exemplary step that is described as "based on condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on."

[0259] Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that can be accessed by a general purpose or special purpose computer. By way of example, and not limitation, non-transitory computer-readable media can comprise RAM, ROM, electrically erasable programmable ROM (EEPROM), compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that can be used to carry or store desired program code means in the form of instructions or data structures and that can be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include CD, laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

[0260] The description herein is provided to enable a person skilled in the art to make or use the disclosure. Various modifications to the disclosure will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein, but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. A method comprising:

receiving, from a wearable device, physiological data associated with a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data;

inputting, using one or more processors, the physiological data into a machine learning model based at least in part on receiving the physiological data;

determining, using the one or more processors, a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data;

identifying, using the one or more processors, that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series;

detecting, using the machine learning model, an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user; and

generating a message for display on a graphical user interface of a user device that indicates the indication of the condition of mental or emotional distress.

2. The method of claim **1**, further comprising:

computing a delta in the time series of the plurality of temperature values based at least in part on determining the time series, wherein identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values is based at least in part on computing the delta.

3. The method of claim **1**, wherein the physiological data further comprises sleep data, the method further comprising:

determining that a quantity of detected sleep disturbances from the received sleep data exceeds a prenatal, perinatal, or postnatal baseline sleep disturbance threshold for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the quantity of detected sleep disturbances exceeds the prenatal, perinatal, or postnatal baseline sleep disturbance threshold for the user.

4. The method of claim **3**, further comprising:

determining that the sleep data deviates from a prenatal, perinatal, or postnatal baseline sleep threshold for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the sleep data deviates from the prenatal, perinatal, or postnatal baseline sleep threshold for the user.

5. The method of claim **1**, wherein the physiological data further comprises heart rate variability data, the method further comprising:

determining that the received heart rate variability data is less than a prenatal, perinatal, or postnatal baseline heart rate variability for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the received heart rate variability data is less than the prenatal, perinatal, or postnatal baseline heart rate variability for the user.

6. The method of claim **1**, wherein the physiological data further comprises low frequency heart rate variability data, the method further comprising:

determining that the received low frequency heart rate variability data deviates from a prenatal, perinatal, or postnatal baseline low frequency heart rate variability for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the received low frequency heart rate variability data deviates from the prenatal, perinatal, or postnatal baseline low frequency heart rate variability for the user.

7. The method of claim **1**, wherein the physiological data further comprises heart rate data, the method further comprising:

determining that the received heart rate data deviates from a prenatal, perinatal, or postnatal baseline heart rate for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the received heart rate data deviates from the prenatal, perinatal, or postnatal baseline heart rate for the user.

8. The method of claim **1**, wherein the physiological data further comprises respiratory rate data, the method further comprising:

determining that the received respiratory rate data deviates from a prenatal, perinatal, or postnatal baseline respiratory rate for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the received respiratory rate data deviates from the prenatal, perinatal, or postnatal baseline respiratory rate for the user.

9. The method of claim **1**, wherein the physiological data further comprises blood oxygen saturation data, the method further comprising:

determining that the received blood oxygen saturation data deviates from a prenatal, perinatal, or postnatal baseline blood oxygen saturation for the user for at least a portion of the plurality of days, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on determining that the received blood oxygen saturation data deviates from the prenatal, perinatal, or postnatal baseline blood oxygen saturation for the user.

10. The method of claim **1**, further comprising:

receiving, via the graphical user interface, a user input comprising a confirmation of the condition of mental or emotional distress, one or more pregnancy symptoms, one or more postpartum symptoms, or a combination thereof, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on receiving the user input.

11. The method of claim **1**, further comprising:

receiving, via the graphical user interface, a user input indicating an age of the user, a body mass index of the user, a medical history of the user, an indication of birth, an indication of a pregnancy mode, an indication of a postpartum mode, one or more tags, one or more surveys, or a combination thereof, wherein detecting the indication of the condition of mental or emotional distress is based at least in part on receiving the user input.

12. The method of claim **1**, further comprising:

estimating a likelihood of a future condition of mental or emotional distress during the prenatal, perinatal, or postnatal period of pregnancy based at least in part on identifying that the plurality of temperature values deviates from than the prenatal, perinatal, or postnatal baseline of temperature values.

13. The method of claim **1**, further comprising:

updating a Readiness Score associated with the user, an Activity Score associated with the user, a Sleep Score associated with the user, or a combination thereof, based at least in part on detecting the indication of the condition of mental or emotional distress.

14. The method of claim **1**, further comprising:

transmitting the message that indicates the indication of the condition of mental or emotional distress to the user device, wherein the user device is associated with a clinician, the user, or both.

15. The method of claim **1**, further comprising:

causing the graphical user interface of the user device to display pregnancy symptom tags, postpartum symptom tags, stress symptom tags, or any combination thereof, based at least in part on detecting the indication of the condition of mental or emotional distress.

16. The method of claim **1**, further comprising:

causing the graphical user interface of the user device to display the message associated with the indication of the condition of mental or emotional distress.

17. The method of claim **16**, wherein the message further comprises a time interval that the condition of mental or emotional distress occurred, a time interval that the condition of mental or emotional distress is predicted to occur, a request to input symptoms associated with the condition of mental or emotional distress, educational content associated with the condition of mental or emotional distress, an adjusted set of sleep targets, an adjusted set of activity targets, recommendations to improve symptoms associated with the condition of mental or emotional distress, a recommendation to consult a clinician, a risk score associated with the condition of mental or emotional distress, or a combination thereof.

18. The method of claim **1**, wherein identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user comprises:

determining that a timing of a maximum temperature value, a minimum temperature value, or both, from the plurality of temperature values deviates from a baseline timing of a baseline maximum temperature value, a baseline minimum temperature value, or both, from the prenatal, perinatal, or postnatal baseline of temperature values.

19. The method of claim **1**, wherein the wearable device comprises a wearable ring device.

20. A system for identifying prenatal, perinatal, or postnatal mental or emotional distress, comprising:

a wearable device configured to measure physiological data from a user that is experiencing a prenatal, perinatal, or postnatal period of pregnancy, the physiological data comprising at least temperature data;

a user device configured to receive, from the wearable device, the physiological data measured from the user by the wearable device; and

one or more servers configured to:

input, into a machine learning model, the physiological data based at least in part on receiving the physiological data;

determine a time series of a plurality of temperature values taken over a plurality of days based at least in part on the received temperature data;

identify that the plurality of temperature values deviate from a prenatal, perinatal, or postnatal baseline of temperature values for the user based at least in part on determining the time series;

detect, using the machine learning model, an indication of a condition of mental or emotional distress based at least in part on identifying that the plurality of temperature values deviate from the prenatal, perinatal, or postnatal baseline of temperature values for the user; and

generate a message for display on a graphical user interface of the user device that indicates the indication of the condition of mental or emotional distress.

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